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NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO TECHNICAL REPORT 18

Virtual Reality: State of Military Research and Applications in Member Countries

(La réalité virtuelle: L'état actuel des travaux de recherche et des applications militaires dans les pays membres de l'Alliance)

Report of the RTO Human Factors and Medicine Panel (HFM).

Published February 2003

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also coordinates RTO's cooperation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of initial cooperation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier cooperation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Virtual Reality: State of Military Research and Applications in Member Countries

(RTO TR-018 / HFM-021)

Executive Summary

NATO Research Study Group 28 (RSG 28), now Human Factors and Medicine, HFM-21, was established to: 1) identify human factors issues involved in the use of VR technology for military purposes; 2) determine the state of knowledge with regard to those issues; and 3) recommend a research agenda that will address critical questions and enable effective products to be produced to meet the military's needs. HFM-21 has adopted the following definition for its use of the term Virtual Reality:

Virtual Reality is the experience of being in a synthetic environment and the perceiving and interacting through sensors and effectors, actively and passively, with it and the objects in it, as if they were real. Virtual Reality technology allows the user to perceive and experience sensory contact and interact dynamically with such contact in any or all modalities.

This is the final report of the Research Study Group (RSG) on Virtual Reality Applications. A summary is presented of three conferences: Workshop on Human Performance Metrics, at Chertsey, Surrey, UK, 15 October 1996; Conference on The Capability Of Virtual Reality To Meet Military Requirements, at Orlando, Florida, USA on 4, 5 & 8 December 1997; and Conference on Industry Capability at The Hague, The Netherlands on 13 - 15 April 2000. Conclusions are drawn and recommendations presented in this report. In addition, member nations present a summary of where they were in VR when RSG-28 was established, and where they are as HFM-21 draws to a close.

The Human Performance Metrics workshop produced NATO Technical Proceedings AC/243(Panel 8)TP/11, Workshop on Human Performance Metrics, edited by Neil Hardinge. The two broad aims included exchange of information and coordination with the UK MoD. That was accomplished. In addition, the RSG suggested that a common toolset of metrics should be developed for VR. This was seen as a way to improve effectiveness of measurement in VR, optimize performance in VR, and increase comparability of systems across member nations.

The Conference on Military Requirements resulted in a series of presentations that were captured on a CD-ROM by Dr. Steve Goldberg, Army Research Institute of the US, and distributed to national leaders of member nations. A draft technical report by Dr. Goldberg summarizing the meeting was in press as of this writing. Presentations included military applications and research requirements. In particular, human factor issues included sensory interfaces, measures of effectiveness, sense of presence and physiological side effects of VR. Applications included systems for dismounted combatants, mission rehearsal for special operations, training, telerobotics, and military medical procedures. An open issue remains with the development of a proper Human Computer Interface (HCI). Examples of needed improvements included helmet mounted displays, physiological side effects protocols, and interfaces for limbs such as haptics and locomotion. Recommendations included the need for advancements in usability methods and tools, and on cost avoidance by having military research focus only on needs not addressed by developers of VR systems intended for related uses.

The Conference in The Hague on What Is Essential for Virtual Reality Systems to Meet Military Human Performance Goals produced extensive proceedings including papers, proceedings and a Technical Evaluation Report (TER) that suggested not only where various member countries stand with regard to VR research and applications, but also suggested future integration of VR with Education (distance learning), the entertainment gaming industry (warfighter skills) and the internet (distribution infrastructure). RTA, NATO, will publish the TER and proceedings.

General findings in The Hague report include the fact that the key to the effectiveness of virtual reality for military purpose is the man-machine interface or human-computer interaction. Military personnel must be able to perform their tasks and missions using virtual reality sensory display devices and response devices. These devices must display an environment that provides the appropriate cues and responses needed to learn and perform military tasks. Human factors issues include: determining the perceptual capabilities and limitations of sensory display devices; designing terrain data bases and other displays to meet task performance needs; understanding the human and task performance compromises required by current technologies; evaluating transfer of training and knowledge from the virtual to the real world; and considering the causes and solutions to simulator sickness that can occur in virtual reality.

Recommendations from The Hague Workshop include, in general, that better co-ordination between military organizations, industry and academia is essential in order to identify gaps in current knowledge and co-ordinate research. To this purpose the military should develop a vision on the use of VR technology and specify their needs more clearly. Industry should work on standardization and should substantially implement human factors into their development process. Academia and research institutes should co-ordinate and accelerate their long-term research efforts to focus on natural interfaces (innovative metaphors) and on how to model human and object behavior. In the short term academia should focus on human factors metrics and metrics for team performance (cognition, communication), and a standard evaluation methodology.

A specific suggestion made during the workshop that could contribute to solving the bottlenecks is to establish an open NATO specialist group to:

- identify killer applications;
- identify a target list of user requirements and technologies for investment by the military;
- foster development of natural VR interfaces and behaviorally realistic intelligent agents and models;
- bringing together interdisciplinary groups and create common vocabulary on shared problems;
- create a research network and identify new funding sources;
- share software libraries and create a central depository of devices and modules; and
- open the non-classified publication of results to other organizations.

Special thanks go to each of the representatives of the member nations for their diligence and cooperation. Without their hard work, this report would not be possible.

La réalité virtuelle: L'état actuel des travaux de recherche et des applications militaires dans les pays membres de l'Alliance

(RTO TR-018 / HFM-021)

Synthèse

Le groupe 28 d'étude OTAN pour la recherche (RSG28), désormais connu sous l'appellation HFM-021, a été créé afin de : 1) identifier les aspects facteurs humains de la mise en œuvre de technologies de réalité virtuelle (VR) à des fins militaires; 2) déterminer l'état actuel des connaissances dans ce domaine; et 3) proposer un programme de recherche pour examiner les questions essentielles et permettre la fabrication de produits susceptibles de répondre aux besoins exprimés par les militaires. HFM-021 a adopté la définition suivante du terme « réalité virtuelle » :

La réalité virtuelle est le fait de se trouver dans un environnement synthétique, de le percevoir et d'interagir avec cet environnement et les objets qu'il contient, par l'intermédiaire de capteurs et d'effecteurs actifs et passifs, comme s'ils étaient réels. Les technologies de la réalité virtuelle permettent à l'utilisateur de percevoir et de ressentir des contacts sensoriels et d'interagir de façon dynamique avec de tels contacts dans un nombre illimité de modalités.

Ceci est le rapport final du RSG sur les applications de la réalité virtuelle avec un résumé de trois conférences : un atelier sur « le paramétrage des performances humaines » organisé à Chertsey, Surrey, UK, le 15 octobre 1996; une conférence sur « La réalité virtuelle peut-elle répondre aux besoins militaires », organisée à Orlando, en Floride, USA, les 4, 5 et 8 décembre 1997; et une conférence sur « La capacité de l'industrie », organisée à La Haye, (Pays-Bas), du 13 au 15 avril 2000. Ce rapport fait état des conclusions et recommandation. En outre un résumé de la situation de chacun des pays participants en matière de réalité virtuelle est présenté au moment de la création de RSG-28 et à la fin des travaux de HFM-021.

Les activités de l'atelier sur le paramétrage des performances humaines ont été résumées dans le compte rendu AC/243(Panel 8)TP/11 « Atelier sur le paramétrage des performances humaines », rédigé par Neil Hardinge. Les objectifs principaux de cet atelier qui étaient l'échange d'informations et la coordination avec le Ministère de la défense britannique ont été été atteints. Accessoirement, le RSG a proposé que soit développée une « boîte à outils » de paramétrage commune à l'ensemble de la VR. Cette proposition a été perçue comme un moyen d'améliorer l'efficacité du paramétrage de la VR, d'optimiser les performances et de faciliter la comparaison des systèmes parmi les pays membres.

La conférence sur les besoins militaires a donné lieu à une série de présentations qui ont été rassemblées sur CD-ROM par le Dr. Steve Goldberg de l'Institut de recherche de l'armée américaine, et diffusées aux membres nationaux des principaux pays. Un projet de rapport technique par le Dr. Goldberg, résumant la réunion, était en cours d'impression au moment où ce texte était rédigé. Les présentations tenaient compte des applications militaires et des besoins en matière de recherche. En particulier, les aspects facteurs humains comprenaient les interfaces sensorielles, l'évaluation de l'efficacité, la sensation de présence et les effets secondaires physiologiques de la VR. Les applications comprenaient les systèmes pour l'infanterie débarquée, la préparation de missions pour les opérations spéciales, l'entraînement, la télérobotique et les procédures médicales militaires. Le développement d'une véritable interface homme-machine (HCI) reste un problème à résoudre. Parmi les améliorations souhaitées figurent les visuels montés sur casque, les protocoles d'effets physiologiques secondaires, et les interfaces haptiques et ambulatoires. Un certain nombre de recommandations ont été faites, à savoir

la nécessité de développer des méthodes et des outils destinés à faciliter l'utilisation de la VR, ainsi que l'importance d'éviter les coûts superflus en focalisant la recherche militaire uniquement sur les besoins négligés par les développeurs de systèmes VR destinés à des application connexes.

La conférence organisée à La Haye sur « Les caractéristiques essentielles des systèmes VR pour atteindre les objectifs militaires en matière de performances humaines » a été résumée dans un compte rendu très complet, comprenant les textes des communications présentées, les délibérations, et un rapport d'évaluation technique (TER), donnant des indications sur la position de différents pays membres vis-à-vis de la recherche et des applications de la VR, qui a aussi proposé la future intégration de la VR dans des activités pédagogiques (enseignement à distance), dans l'industrie des jeux vidéo (compétences du combattant) et sur Internet (infrastructures de distribution). Le TER et le compte rendu seront prochainement édités par la RTA de l'OTAN.

Les conclusions générales du rapport de La Haye mentionnent le fait que la clé de l'efficacité de la VR pour des applications militaires se trouve dans l'interface et l'interaction homme-machine. Le personnel militaire doit pouvoir exécuter les tâches et les missions qui lui sont confiées à l'aide de visuels et de répondeurs sensoriels VR. Ces dispositifs doivent être en mesure de présenter un environnement qui fournit les stimulations et les réponses nécessaires à l'apprentissage et à l'exécution des tâches militaires. Les aspects facteurs humains comprennent : la détermination des capacités perceptives et des limitations des visuels sensoriels; la conception de bases de données de terrain et d'autres présentations visuelles afin de réaliser les tâches imposées; la connaissance des compromis imposés par les technologies actuelles au niveau de l'homme et de l'exécution des tâches; l'évaluation des conséquences du transfert de la formation et des connaissances du monde virtuel au monde réel; et l'analyse des causes et des solutions au mal de simulateur qui est parfois associé à la VR.

L'atelier de La Haye a conclu que de façon générale, il est indispensable d'assurer une meilleure coordination entre les organisations militaires, l'industrie et les universités, afin d'identifier les éventuelles lacunes dans les connaissances et de coordonner les travaux de recherche. Avec cet objectif en vue, les militaires devraient élaborer une philosophie de mise en œuvre des technologies VR et exprimer leurs besoins plus clairement. L'industrie devrait travailler sur la normalisation et faire une large place aux facteurs humains dans ses processus de développement. Les universités et les instituts de recherche devraient coordonner et intensifier leurs efforts de recherche à long terme afin de se concentrer sur les interfaces naturelles (métaphores novatrices) et sur la modélisation (intelligente) du comportement des objets et des êtres humains. A court terme, les universitaires devraient privilégier la métrologie des facteurs humains et la métrologie du travail en équipe (l'approche cognitive, la communication), ainsi que l'élaboration d'une nouvelle méthodologie normalisée d'évaluation.

L'une des propositions faites pendant l'atelier, qui pourrait contribuer à résoudre les problèmes d'engorgements, était de créer un groupe ouvert de spécialistes OTAN afin de :

- identifier des applications éliminatrices;
- identifier une liste d'objectifs du point de vue des besoins des utilisateurs et des technologies afin d'orienter les investissements militaires;
- encourager le développement d'interfaces VR naturelles, d'agents et de modèles intelligents à comportement réaliste;
- rassembler des groupes pluridisciplinaires et créer un vocabulaire commun pour les problèmes communs;
- créer un réseau de recherche et identifier de nouvelles sources de financement;
- partager les logithèques et créer un dépôt central de dispositifs et modules; et,
- diffuser les résultats non classifiés à d'autres organisations.

Nous tenons à remercier chacun des représentants des pays membres pour leur assiduité et leur coopération. Sans leurs efforts, ce rapport n'aurait pu être publié.

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INTRODUCTION

Our group's definition of virtual reality states that it is a "*Multidimensional human experiences which are totally or partly computer generated and can be accepted by the participants as consistent."*

It is not necessary for a virtual world or virtual environment to be an exact copy of the real world. It is sufficient to have an artificial world in which it is possible to work in much the same way as in the real world. Virtual worlds can be schematic and/or augmented. To be coherent the worlds generated by computer must provide sensations or illusions of sensations that correspond to those that are experienced in the real world.

Also the actions that are under taken in virtual worlds should correspond to actions under taken in the real world. For this to happen it is necessary for the same cues to be present in the virtual world as in the real world in order to initiate and sustain performance, these cues or stimuli are delivered through interface technologies to individuals immersed in the virtual world. It is also necessary to provide interfaces that allow for appropriate responses to the stimuli. Designers of virtual environments need to be aware of affective and social interactions involved in their application. They also need to be aware of the differences between the virtual world and the real world and the possible problems these differences could cause (e.g. negative training). **Means for the individual in first part to know the information pick-up modes, the intellectual operations and actions, in second part the affective reactions and the social interactions in the world real, and in final part to know the differences that can to be with using interfaces in the applications of this techniques and to remember that this differences can to conduct at a veritable pathology of immersions.**

To respond to these different issues, it is necessary to first think about the concepts of reality and virtuality and second about the military applications of virtual reality and their place among all the simulations in use today. There has been significant growth in the technologies supporting virtual reality simulation in the years since this Research Study Group began. It is possible today to develop applications that were not impossible then. These changes will effect will our conclusions and recommendations.

This report summarizes the activities of a NATO Research Study Group organized to consider human factors issues in the use of virtual reality for military applications. During the course of the five years since the study group was formed it has written a number of reports and held three work shops. The body of this report contains summaries of these reports and work shops. The text of the reports and the proceedings of the workshops are presented in full in the appendices.

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1.0 - The Real and The Virtual

Reality is the real world, but each persons reality is their cognitive representation of the real world.

In English, virtual means in fact (he's the virtual head of the business). Virtual reality is the reality, in fact, where it is possible to live and to work. In French the translation of "réalité virtuelle" is not the same as in English, because the definition of "virtuel" is probably and not in fact. It is only in optics where virtual is same in English and French. The virtual image is the perceived image, the continuation of visual rays versus a real image by example of sun that is capable of doing the energy to light a paper (figure 1). But in virtual reality the images are real. In French a better translation is "réalité vicariante" or substitute reality.

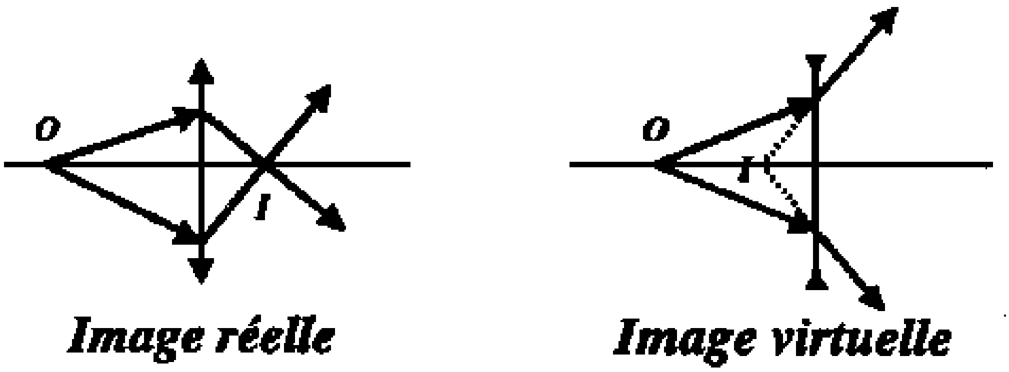

Figure 1: Real image and Virtual image

1.1 Virtual Reality and Simulations

1.1.1 The Different Simulations

1.1.1.1 Live Exercises

Live simulations are exercises where terrain, soldiers and weapon systems are real, but the situation (engagement simulation) and use of the weapon (as plaster grenade or laser bullets) are artificial. The first goal of live simulation is human learning and training. However, recently live simulation has also been used to evaluate new tactical concepts, and to study the effects on materiel and soldiers of various combat situations and tactics. For example experiments can be used to study the effects of partial sleep deprivation on performance during a three weeks exercise.

1.1.1.2 The Special Tracks

Where the environment is recreated, the equipment and the human are real.

Figure 2: Example of special track (pothole) in Etablissement technique d'Angers (ETAS)

1.1.1.3 The Test Bench

Where physical environment is simulated and the equipment or equipment parts are real.

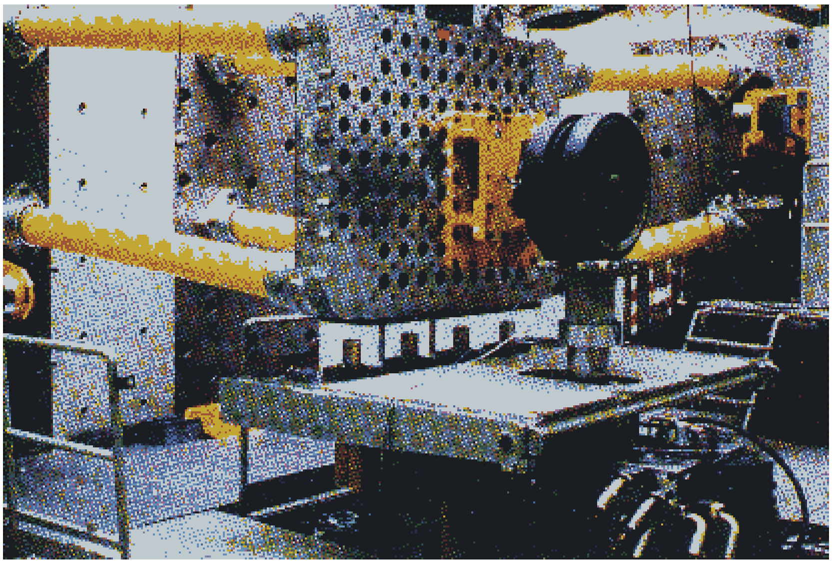

Figure 3: Example of a bench test of a vehicle suspension at ETAS

1.1.1.4 The Computer-Generated Simulation

Where everything is simulated: environments, equipment, men and task. These simulations are mathematical and can be represented by a symbolic display. An example of a computer-generated simulation is the "microsaint" tool (figure 4).

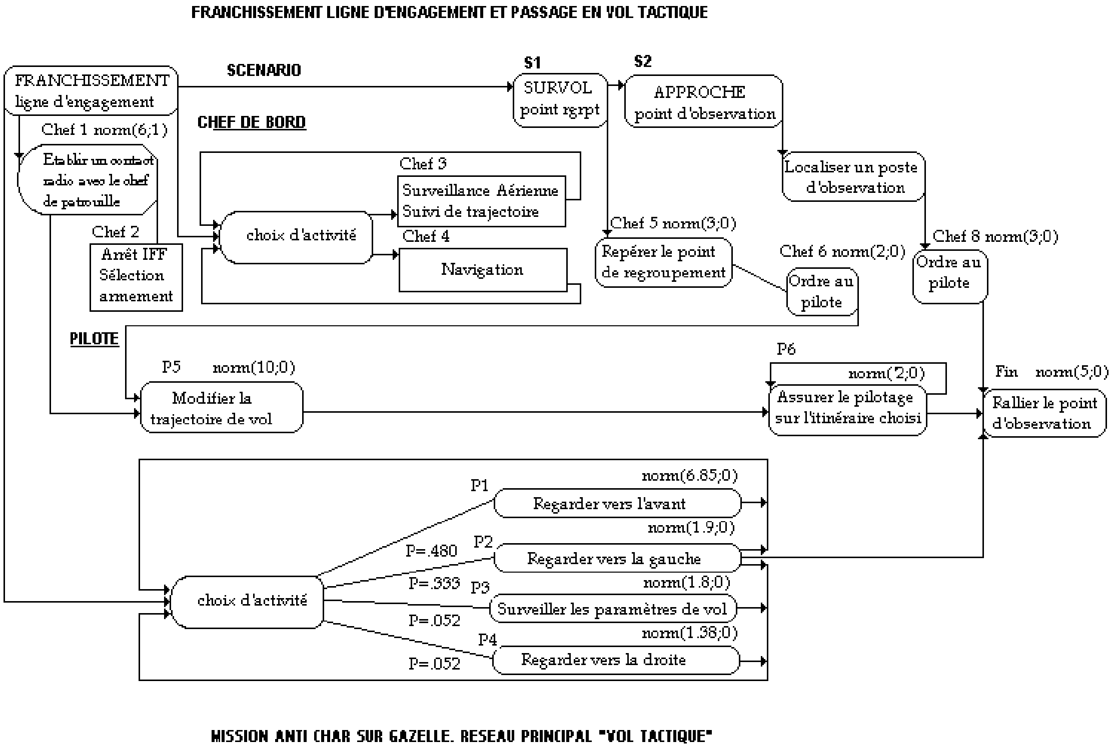

Figure 4: Representation of tank crew behaviour with MICRO-SAINT

Sometimes computer simulations can be very realistic. For example, the use of the Virtualman tool produces a very lifelike looking avatar (figure 5). This tool uses mathematics to produce a 3D body representation. It allows one to manipulate posture and movement of the manikin. The user of this type of software tool is manipulating a virtual environment but is not immersed in the environment as in virtual reality. But is possible to use these techniques in virtual reality to create autonomous agents that function as actors in the environment. Virtual environments are computer simulations however, in order to have virtual reality, it is necessary to have immersion and bilateral interaction.

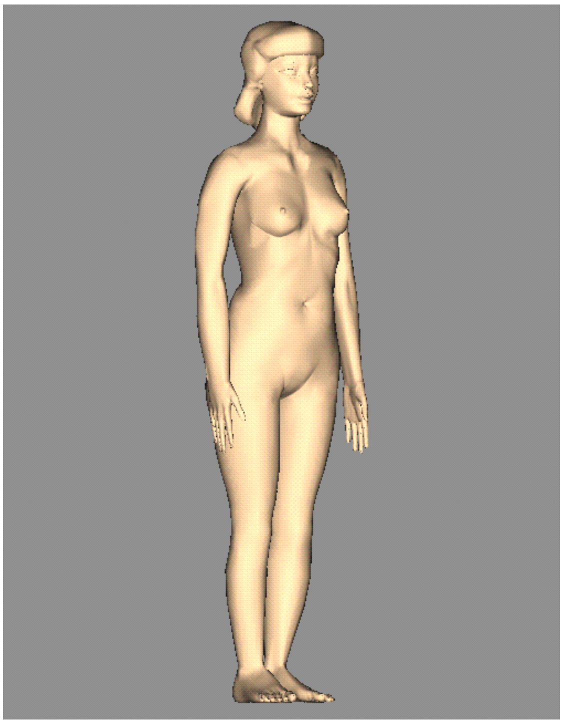

Figure 5: Surfaced body representation with dual “Krige"

1.1.1.5 The Virtual Reality

In virtual reality, we generate environments by computer that can be modified by an operator. Based on the operator's actions the environment reacts appropriately and provides him with new sensory inputs. In a complete virtual reality interfaces directly excite the sense organs and should provide an illusion of real sensations. Unlike other computer simulations, Virtual Reality must take place in real time.

The JEDI clothes proposed by Burdea (figure 6) are an example of the type of interface technologies necessary to create the illusion of a virtual reality.

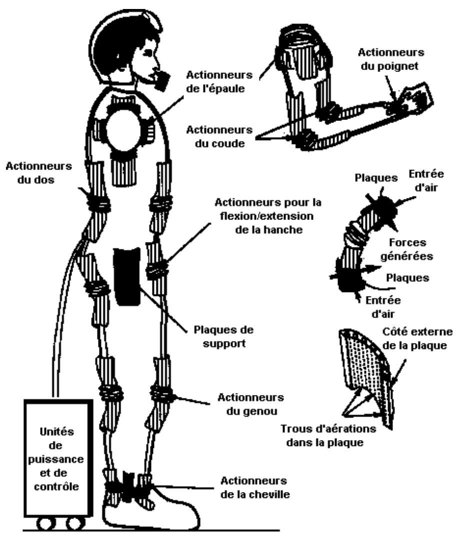

Figure 6: The clothes JEDI (Burdea and al, 1991)

1.2 Remarks on Virtual Reality

When we use virtual reality in military applications it is necessary to know the effects of the interfaces on perception and human performance. It is also necessary to have an understanding of the psychological and sociological effects the simulation will have on the individuals participating in the simulation. Test tools are needed to obtain this information. The Research Study Group has looked at the availability of the tools to evaluate the effectiveness of virtual realities. Another important question to consider is whether or not it is necessary to construct a complete virtual reality for each application or is it possible to meet objectives with a simulation that provides a functional or psychological reality. A functional reality is not a copy of the real world but a virtual space of activity that provides an operator the necessary cues and response options to perform specified tasks. This type of environment has elements that have been either simplified and/or augmented to provided added information during training, as is the case with the speeds vector in a virtual pilots heads up display (figure 7).

For some military applications it is possible to immerse the man in a visual virtual reality but still provide proximal tools that are real. An example of this is a parachute simulator (figure 8).

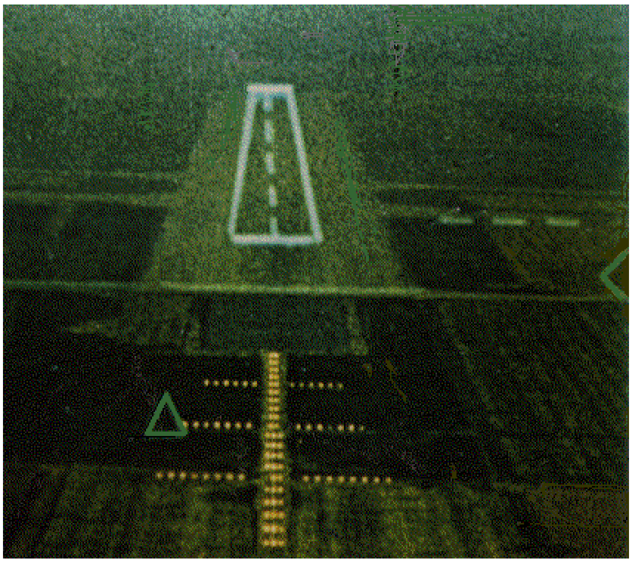

Figure 7: Augmented reality, projection of speeds vector (triangle) on the head-up display. (Santucci and all 1981)

Figure 8: Simulator of parachute (ETAS)

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2.0 - The Military Applications

These applications are presented in function of their finality (conception, test, training and learning, action preparation, and real actions in situ or at distance). For each just one example from a state is given.

2.1 Help to Concept the Weapon Systems

In each phase of weapon system definition it is possible to simulate the architecture, the man-machine interface, or task workload with virtual reality. This approach represents a cultural revolution in which materiel developers can develop concepts and evaluate them with operators in the loop long before metal is bent and physical prototypes are developed. For example figure 9 shows an apparatus developed by The Netherlands for evaluating new ship concepts.

Figure 9: Virtual reality apparatus to concept a work station in a ship

2.2 Help to Evaluate and to Test the Weapon Systems

After concept development it is possible to test future materiel in virtual reality with real soldiers and not just with professional testers. The proposed equipment can be put into situations that would be difficult to attain in test centres because of safety and other practical considerations. Figure 10 shows an example of driving a simulated armoured vehicle.

Figure 10: Test driving future vehicle

2.3 Training and Learning Applications

The use of virtual reality for training and learning is an extension of earlier training simulators originally developed many years ago for training aircraft pilots. Today virtual reality can provide a training tool for army, navy, staff and medical corps.

Virtual reality has a number of important advantages for training. They can provide soldiers with experience operating in many different types of environments. The same virtual reality computer system can possibility be used to simulate different weapon systems and situations.

The cost/effectiveness of virtual reality training applications need to be assessed to evaluate the part virtual reality should play in training of weapon systems and tactics. Below are some examples of the use of virtual reality for training applications.

2.3.1 For air force with an example of flight simulator use in Denmark (figure 11)

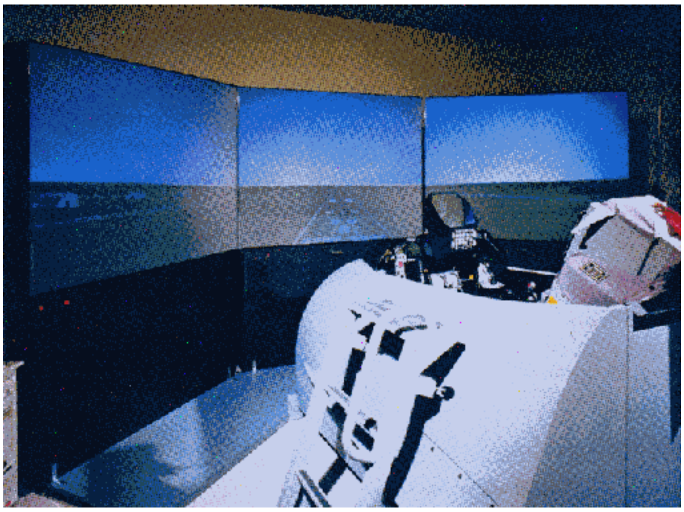

Figure 11: Flight simulator use in Denmark

2.3.2 Naval simulator for training re-supply operation in the USA (figure 12)

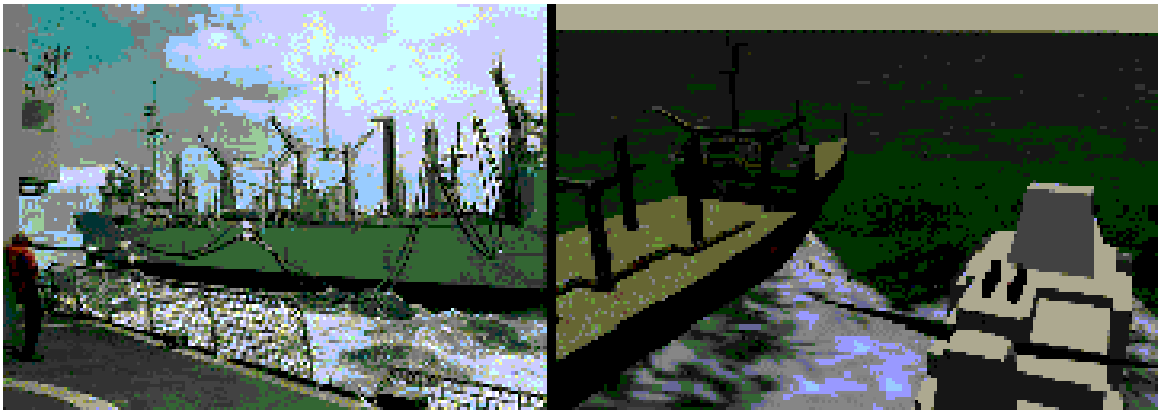

Figure 12: Transhipment Simulator

2.3.2 German Army Stinger Simulator

Figure 13: Stinger Simulator

2.3.3 The French Medical Corps Reanimation Simulator

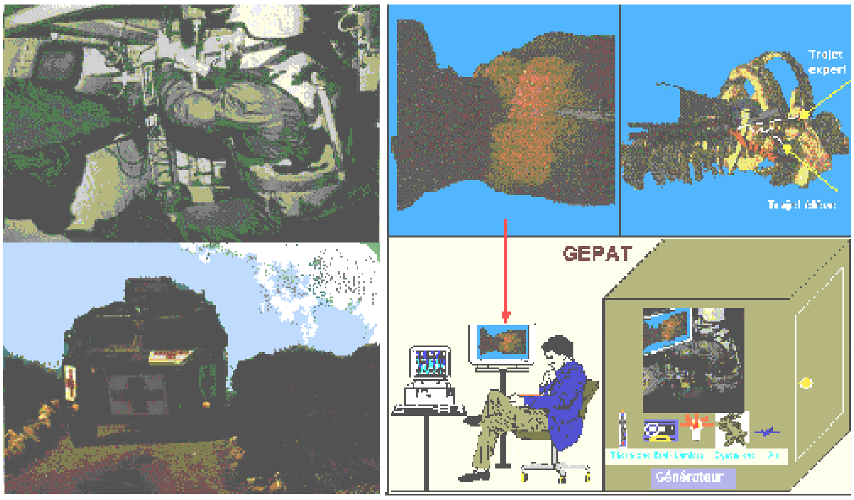

Figure 14: Reanimation Simulator

2.4 Help for Mission Planning and Rehearsal

For this application a major requirement is use of a virtual environment that accurately represents the actual terrain on which an operation will be conducted. Figure 15 is a picture of a robot used to clear mines in United Kingdom. Next to the picture of the actual robot is a virtual representation of the equipment. The virtual simulation permits operators to plan and practice routes they would use in disarming actual mines.

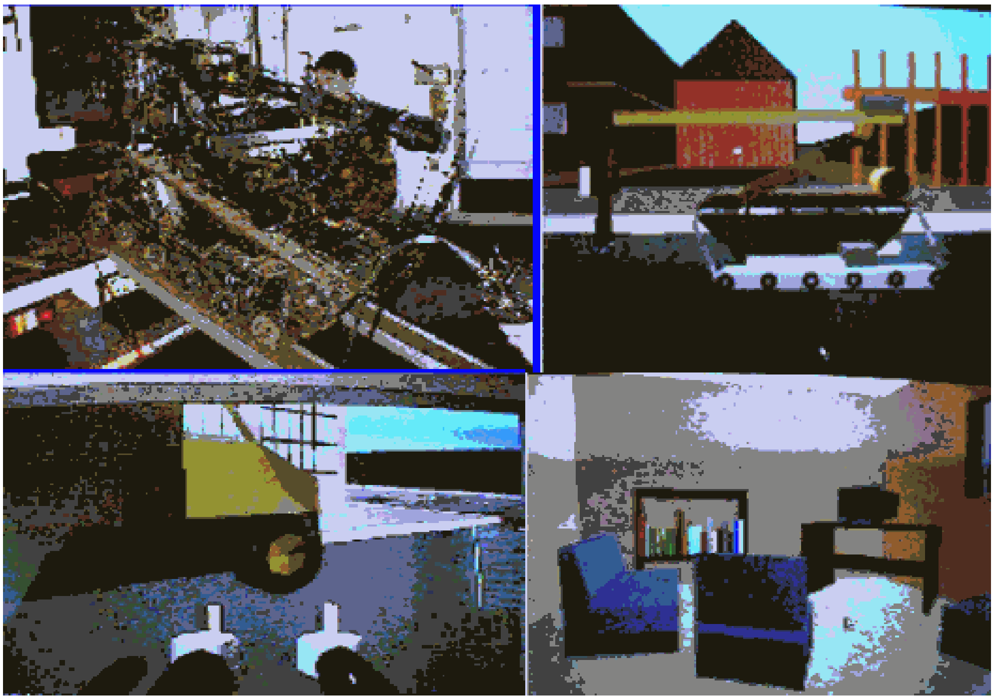

Figure 15: Virtual robot and environment to clear a filed of mines

Learning to handle situations soldiers might encounter in peacekeeping and other contingency operations requires interactions with civilians in potentially threatening situations. For these types of missions use very realist intelligent avatars such as the English ANANOVA provides for realistic interactions between soldiers and civilians (figure 16). The United States has been developing scenarios to train soldiers how to man a checkpoint. A key element of the scenarios is use of intelligent avatars.

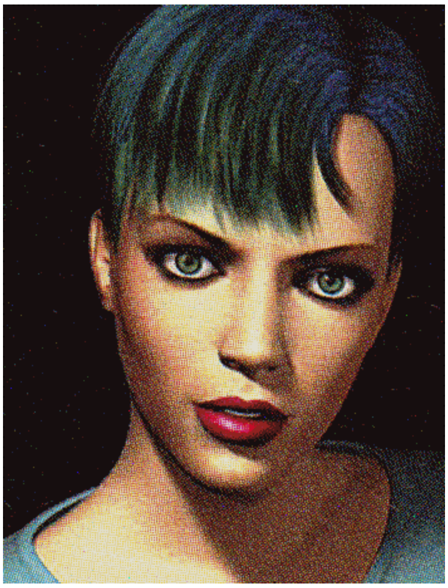

Figure 16: ANANOVA (EUREKA April 2000)

2.5 Real Mission Application

In France a special apparatus has been developed to permit to drive a vehicle in real time in first time with augmented presentation and in second time with 3D virtual representation of land and a GPS (figure 17).

Real image with virtual information virtual driving with God eye

Figure 17: Using of the virtual reality to drive a vehicle in real time

In Germany a system of following tactical operation is in development with a workbench (figure 18).

Figure 18: Representation of Tactical Situations

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3.0 - Human Computer Interaction Report (Summary)

3.1 Purpose

The purpose of this report is to present a collection of papers commissioned by RSG28 that cover the state-of-the-art of human computer interfaces for the various senses that could be used to provide a virtual world in which to accomplish military goals and requirements.

3.2 Summary

The first paper addresses topic of visual environment building. It was written by Antonio Gramage. His paper reviews the variables that interact to form the visual scenes within virtual environments. The topics covered include geometric modeling, morphing, texture maps and billboard objects, lights, viewpoints, object behaviors, interaction feedback. The paper also discusses human visual capabilities and how these have to be taken into account in the design of visual data bases. The paper concludes by presenting areas for future study. These include sickness in virtual environments, evaluating low fidelity solutions, and development of a common tool set for assessment of performance in virtual environments.

The paper by P. Werkhoven, R. Drullman, and A.W. Bronkhorst reviews some of the research that has investigated the perceptual issues of participating in immersive virtual environments. The two areas focused on are visual and auditory perception. For each of these areas the paper discusses natural performance in the real world and how that performance is likely to be affected by limitations of virtual environments technology. The paper also contains a summary of current research in perceptual issues in virtual environments and suggestions of areas for future research. The focus on the suggestions for future research is on validation, manipulation and navigation for visual perception, and data compression, dynamic scenes and individualization of the technique for auditory perception.

The paper by Thierry Morineau discusses the various technologies that are available to track the position of immersed subjects in virtual environments. The paper also discusses the methods available for locomotion in virtual environments. Morineau concludes that the location of an immersed subject in space and the simulation of movement in the virtual world are key elements in defining a 3-D virtual environment. The choice of location sensors and locomotion interfaces should be determined by a study of all movements which can be envisaged in a given situation to be simulated.

The paper by Jennifer A. Ehrlich, Mar E. Rodriguez and Stephen L. Goldberg summarizes the literature in the area of haptic interfaces. It begins with an overview of what is covered by the term “haptic” and the physiology of tactile stimulation. It then reviews recent research on object manipulation, including what type of information (e.g., compliance, texture, and conductivity, object shape) the user receives in activities such as touching, grasping, and wielding an object. Currently available haptic systems are outlined. Finally, the paper addresses human factors issues for haptic interfaces: ergonomics, training and transfer of training requirements, force and touch feedback needs, simulator sickness, and presence.

Trond Myhrer and Lars Aarhus review the limited research literature on cues that are need to support or enhance situational awareness in virtual reality. The paper presents a definition of the situational awareness construct, followed by a discussion of some examples of visual and auditory cues in virtual environments and how they could affect situational awareness. The authors conclude that given the extent of research in this area much work is need to determine how perceptual cue effects performance in virtual environments.

Clare Regan reviews research that investigates the side-effects on users of participating in immersive virtual environments. The research is discussed with regard to visual and musculoskeletal effects of virtual reality; nausea and related problems; and psychological effects of virtual reality. Areas for

further research are discussed with a focus on: investigating individual differences in susceptibility to virtual reality induced side effects; investigating the importance of the nature of virtual environments in inducing side-effects; and investigating the role that the technical characteristics of the system may play.

3.3 Main Conclusions

Virtual environments technology has made significant progress in producing realistic dynamic environments that can be used for a number of military purposes. The technology, however, is still in its infancy and some problems exist with the interface technologies that allow humans to interact with virtual environments. Visual systems are the furthest advanced. Dramatic growth in capability coupled with lowered prices have made low cost high fidelity visuals possible. Other technologies are not as advanced. Those that sense body position are cumbersome, sometimes slow and inaccurate and subject to interference. Locomotion cannot be accomplished realistically and haptic displays are immature. Also, immersive Virtual Reality can cause subjects to feel discomfort similar to motion sickness. Human Factors issues need to remain a driving consideration in improvements to virtual environments interface devices.

3.4 Major Recommendations

Military research and development efforts at interface design should address only those areas that are not likely to be improved by industrial investment. Efforts should continue to evaluate the capabilities of technologies to meet military requirements and provide industry with feedback regarding the effectiveness of their products within integrated systems designed to meet military needs.

3.5 Military Implications

Use of virtual simulations by the military is increasing dramatically for training, concept development, mission rehearsal, materiel acquisition, and other purposes. Virtual Reality technologies provide promise as a means to directly involve military personnel in virtual environments. Care must be taken that the technologies chosen meet their intended military requirement and do not present an undo risk to health and safety. Review of Virtual Reality technologies and applications will aid in the design of effective applications.

4.0 - Human Performance Metrics (Chertsey Report Summary)

4.1 Summary of the Workshop

The one-day open workshop aimed to: inform the members of RSG28 about the work being conducted on human performance metrics by organisations associated with the UK's defence research programme; to inform these researchers of the RSG's programme of work in this area; and to inform the MOD scientists to whom this work could be of use. The workshop highlighted several different approaches to performance measurement that are being adopted. It identified a wide range of metrics currently in use and it highlighted some of the needs of researchers in the field. The workshop provided a valuable input to the group's subsequent discussions and identified areas where the group could usefully draw upon the wider body of work.

4.2 Main Conclusions

Development of a common toolset of human performance metrics is one of the objectives of the RSG. The main conclusions were that there is:

- a requirement for improved measures of human performance
- a sufficient range of measures and metrics from which a common toolset could be derived
- a good basis for continued work within the group to develop a common toolset
- benefit to be gained from continued exchange of measures, experience and of experimental data between the group and the other researchers in this field.

4.3 Major Recommendations

Since the workshop was to inform the members of the RSG 28, no specific recommendations were made. The current status of human performance measurement was presented to the members. The general recommendation were that the group should continue to develop a common toolset of metrics and that benefits and efficiencies would follow from continued exchange of experience between the RSG and the other researchers.

4.4 Military Implications

The benefits of improved measurement, through use of a common toolset of human performance metrics in virtual reality systems, include the following:

- more effective ways of measuring human performance
- improved ways of optimising HF performance in VR systems
- increased scope for comparability between:
    - international studies
    - different VR solutions
    - VR and non-VR solutions

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5.0 – The Capability of Virtual Reality to Meet Military Requirements (Orlando Report Summary)

5.1 Purpose

The purpose of the workshop was to examine military requirements for Virtual Reality technology, consider human factors issues in the use of Virtual Reality and review recent research in development of Virtual Reality applications to meet military needs.

5.2 Summary

The workshop was organized into three daylong sessions. The first day focused on military applications for Virtual Reality systems and identified particular requirements for Human Factors research to meet the requirements. The second day examined Human Factors issues in the use of Virtual Reality technology. Presentations discussed sensory interfaces, measures of effectiveness, importance of the sensation of presence, and cybersickness. The third day reviewed assessment methods and applications research. Speakers reviewed existing or completed Virtual Reality projects designed to meet military needs. The papers discussed how the projects overcame human factors problems and how their effectiveness was evaluated. Summaries of the paper presentations are incorporated in the chairman's notes for each day of the workshop.

5.3 Main Conclusions

Virtual Reality technology is of great interest to the military. Requirements for its use encompass a wide range of applications including concept development of systems for dismounted combatants, mission rehearsal for special operations, training ship handling skills, telerobotics, and practicing military medical procedures. Virtual Reality's success in meeting these needs will be determined by the ability of its human-computer interfaces to provide the means necessary to deliver stimuli and allow appropriate responses from those using it. These human factors issues were the focus of the workshop. Through research on Virtual Reality's interface technologies and applications, it is clear that Virtual Reality has promise for the military, but serious human-computer problems limit its potential. In particular, helmet mounted displays need to be improved, cybersickness limits use by a significant number of people, haptics and walking interfaces are in their infancy. The workshop pointed to these and other areas that require further research and development in order for Virtual Reality to meet its potential for the military.

5.4 Major Recommendations

Research needs to continue on the many human factors issues involved in the use Virtual Reality to meet military requirements. The Virtual Reality technologies are maturing and the feasibility of developing cost-effective Virtual Reality based tools is increasing. Research on the usability of this technology will enable militaries to be smart buyers. It will ensure that Virtual Reality hardware and software is capable of meeting the perceptual, fidelity, transfer of training, and health and safety requirements of applications. Military research needs to focus on those issues that are unique to the military and not likely to be address by other potential users of Virtual Reality.

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6.0 - Industry Capability (The Hague Report Summary)

The workshop was organized into three daylong sessions. The first day focused on functional requirements for military VR applications in the domains of training, robotics, remote operations and command and control. On the second day, we examined available VR techniques now and in the near future. Presentations discussed visual, haptic, auditory and motion feedback, navigation interfaces, and scenario generation, modeling software and rendering hardware. The third day addressed missing VR capability and future research and concluded with a panel discussion.

During the workshop discussions forty participants from military organizations, academia and industry put forward their opinions on the biggest bottlenecks and opportunities in the development of military VR applications.

6.1 Main Conclusions

Virtual Reality technology is of great interest to the military. Its most important application domain is training. VR for training can reduce cost and risk of casualties and improve flexibility and performance monitoring. Furthermore, great opportunities are identified in the domains of planning and mission rehearsal, simulation supported operation, remotely operated systems and product design.

At the same time a number of factors seem to frustrate successful applications in this field. One of the significant bottlenecks is that VR developments are usually not user driven. Application developers and designers do not pay enough attention to human factors requirements. Consequently, applications may fail because of a lack of natural interfaces and motion sickness. So far, user interfaces have been poorly attuned to natural human skills (crude input devices and inconsistent visual, auditory and proprioceptive feedback) and to the tasks to be performed in VR. A second bottleneck is the lack of standardization causing problems with integrating VR systems and VR software tools. A third is the lack of behavioral models of people and objects in VR scenarios and facilities for team interactions (poor visual human representations and communication tools).

6.2 Major Recommendations

In general, better co-ordination between military organizations, industry and academia is essential in order to identify gaps in current knowledge and co-ordinate research. To this purpose the military should develop a vision on the use of VR technology and specify their needs more clearly. Industry should work on standardization and should substantially implement human factors into their development process. Academia and research institutes should co-ordinate and accelerate their long-term research efforts to focus on natural interfaces (innovative metaphors) and on how to model human and object behavior. In the short term academia should focus on human factors metrics and metrics for team performance (cognition, communication), and a standard evaluation methodology.

Specific suggestions made during the workshop that could contribute to solving the bottlenecks is to establish an open NATO specialist group to:

- identify killer applications;
- identify a target list of user requirements and technologies for investment by the military;
- foster development of natural VR interfaces and behaviorally realistic intelligent agents and models;
- bringing together interdisciplinary groups and create common vocabulary on shared problems;
- create a research network and identify new funding sources;
- share software libraries and create a central depository of devices and modules; and
- open the non-classified publication of results to other organizations.

Specific suggestions made by this report, having considered VR technology presentations at the workshop as well as related, emerging technologies within the military include:

- increase the synergy between VR and modeling & simulation technology developments;
- leverage current trends of partnering, such that military agencies and government educational agencies combine efforts to provide the critical mass necessary to influence industry and academia toward use of VR in meeting training needs;
- leverage capital investments of distance learning infrastructure development to foster increased applications of VR for training scenarios.

The enthusiasm of the workshop attendees and the evident willingness to share ideas and to discuss their findings provide a promising base for such co-operation.

WHAT IS ESSENTIAL FOR VIRTUAL REALITY SYSTEMS TO MEET MILITARY HUMAN PERFORMANCE GOALS? The simplest answer to this question, which was the topic addressed by the workshop, is continued involvement by NATO members in the application of VR technologies to meeting military requirements. Since VR is an integration of technologies to include modeling, simulation, graphics, haptics and audio, and human factors considerations a multidisciplinary approach is needed. Likewise, NATO will want a central focus of military applications of this very critical training technology. Rapidly reconfigurable, low cost, highly effective training environments don't exist. Pick any two of those criteria and the third becomes unachievable. Yet the promise of VR is the possibility of all three for military training. Such a potential seems well worth continued investment, influence and involvement by NATO member countries.

In addition to M&S, educational applications may also provide an avenue of approach. Many countries are investing in Internet capabilities for their citizens. The network will soon be as comprehensive as the telephone and television. VR immersion technologies and distance learning principles coupled with broadband Internet distribution would eliminate the need for military capital investment and allow cost effective delivery of training materials. Thus, collaboration of military agencies and civilian educational agencies may be a synergy for combined resources, and long term technology development strategy that would provide the critical mass necessary to influence industry and academia toward training needs. NATO member nations could factor this strategy into some of the thinking about operations-other-than-war.

Medical applications present a further avenue. The Human Computer Interface is currently unacceptable for complex systems. Keyboard, joystick and mouse instruments will give way to EEG, voice, haptic and eye interfaces as technology moves toward human-centered design and network-centric warfare. Already, medical applications of VR appear viable for training surgery and diagnostic procedures. Similarities of human functions need further exploration. For example, France reported mine detection training to be very similar to training for medical personnel to insert a needle. Continued analysis for functional similarities between and across disciplines such as medical applications would give additional leverage to military operations training techniques. The work in metaphor development for VR is one step in this direction. Also, continued understanding of internal human communication mechanisms may provide better Human Computer Interfaces than currently exist.

One conclusion is clear. There is no obvious strategy, no clear consensus and no simple combination of techniques to achieve military performance goals using VR. Three possible strategies are presented, above.

7.0 - Member Countries

7A - VR-Projects in Denmark

VR-projects in Denmark can be categorised as either civilian or military. Civilian projects are either commercial or research and development. Those will be mentioned in the next chapter. Military VR-projects are either simulators or research and development. The military projects will be mentioned in the last chapter. A common event for both the civilian and military society is the founding in May 1999 of DK-VRS (Danish Virtual Reality Society).

7A.1 Civilian VR-projects

Commercially VR is user by television stations and advertising agencies. VR in research and development is of growing interest. Two universities have established VR laboratories and a third is in the process of establishing a VR centre. These will be mentioned in the next section. Examples of research and development VR-projects will be mentioned in the following section.

A Danish Virtual Reality Society (DK-VRS) was established in 1999.

7A.1.1 Civilian VR Research laboratories

7A.1.1.1 Centre for Advanced Visualisation and Interaction

CAVI (Centre for Advanced Visualisation and Interaction) is a Centre for IT-research (CIT) project. It is a forum for exchanging information and. The involved parties are Systematic, MR Centre, PET Centre, and the University of Aarhus. The VR-equipment is the following:

- TAN Holobench (horizontal and vertical screens)
- Onyx2 Infinite Reality2 Rack, 6X250 MHZ MIPS R10000, 1.5 Gb RAM, 2 graphics pipelines (each 64 Mb texture memory)
- Polhemus FASTRAK (3 sensors)
- Stereographic glasses.
- 6 Octanes
- 20-30 O2

Several CAVI-projects will be mentioned in a section 7A.1.2.

7A.1.1.2 VR Centre North

VR Centre North is located at the University of Aalborg. It has just been established. Its main feature is:

- Cave with 6 walls (2,5x2,5x2,5 m)
  Active stereo glasses

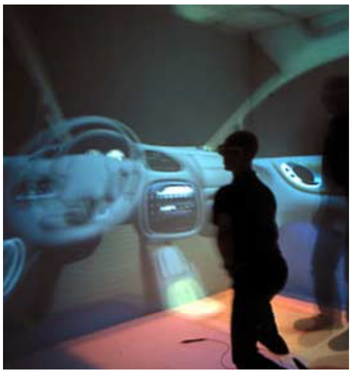

Figure 7A.1: CAVE with 6 walls at Aalborg University

- Powerwall
  Big screen (8mx2.85m)
  Passive stereo glasses
- Panoramic screen
  160-degree screen (diametre 7.1m, hight 3.5m)
  Active stereo glasses
  Magnetic tracking device.

These are run by:

- Onyx2 Infinite Reality2 Rack, 6 graphics pipelines

Figure 7A.2: Onyx2 at Aalborg University

7A.1.1.3 Danish Maritime Institute

Danish Maritime Institute (DMI) has developed great expertise through many years in the area of simulator development and training especially for ships crew.

Figure 7A.3: Ship Simulator

7A.1.1.4 VR•C

In marts 2000 a new VR centre (VR•C) will open at the Technical University (DTU) in Lyngby north of Copenhagen. It is collaboration between UNI•C (a national IT-centre under the ministry of education) and DTU. VR•C will have 2 high resolution VR-helmets and an advanced sound system, and simulations will run on one of Denmark's biggest supercomputers. Keywords for VR•C are industry, education and research.

7A.1.2 Civilian VR Research and Development Projects

3D image processing for cranium- and brain-surgical planning and simulation is a CAVI-project by PET Centre. It is a framework for working with medical images.

Digital, 3D atlas of the receptor systems of the human brain is a CAVI-project by PET Centre.

Computer-based detection of patterns in magnetic-resonance images is a CAVI-project by MR Centre. Uses of texture analysis to analyse the quality of meat.

3D visualisation of human organs is a CAVI-project by MR Centre. The focus is on children's hearts.

Digital Theatre. Visualising human movements using sensors at the University of Aarhus.

Puppet is a research project funded by EU-commission at the University of Aalborg. It involves developing virtual inhabited 3D rooms for educating pre-school children.

Staging of Virtual Inhabited 3D-spaces is a research project funded by the Danish National Research Council involving the University of Aalborg, etc. It deals with all kinds of aspects regarding the nature and usage of the signs system of interactive multimedia; which in general terms means the semiotic of interactive multimedia systems. The purpose is to define a universal common language for 3D interactive multimedia systems.

Sound in Cyberspace is a research project at the University of Aalborg.

3D-visual Data Mining at the University of Aalborg uses VR-facilities to develop dynamic 3D models that can visualise and handle very large statistical data sets.

Rehabilitation of stroke patients using VR is a project at the University of Copenhagen, 3D Lab, Panum Institute.

VR in Neuro Informatic at the Technical University.

Simulating a combine harvester at the Technical University.

Digital 3D-architecture models on the Internet. Pilot project at the Art Academy Architecture School.

Visualising the information in a library system is a prototype at the School of Commerce.

Motion Capture at 3D Connection.

7A.2 Military VR-Projects

Military VR-projects are either ready-made bought simulators or research and development. One exception is **Debriefing System for the Airforce** mentioned below. Military research and development takes place at the Danish Defence Research Establishment.

Debriefing System for the Airforce is a CAVI project by Systematic. It involves modelling, simulation and visualisation of GPS-based time-series data. A holobench version with stereo vision is running at the University of Aarhus.

HCI-Lab. Laboratory at the Danish Defence Research Establishment is use for testing VR hardware and software. In 1999 the laboratory had the following hardware:

- Intergraph TDZ-410 (dual Pentium pro 200MHz)
  256 MB RAM
  64Mb texture memory
  13 GB hard disk
- TDZ 2000 GT1 (dual Pentium II 400MHz)
  256 MB RAM
  VX113, 16 MB texture memory (Will be upgraded to Wildcat)
  35 GB hard disk
- TDZ 2000 GX1 (Pentium II 450MHz)
  256 MB RAM
  Wildcat
  27 GB hard disk

- Assorted PC's
- Ascension's Flock of Birds
- V6 helmet
- I/O glasses
- Gloves
- Logitech Spacemouse

The laboratory has the following software:

- SuperScape
- Sense8
- Multigen Creator

Tactical trainer for a group leader. Research and development project at the Danish Defence Research Establishment. It started 1998, and is a tactical trainer for education and training a group leader. It combines a programmed simulation model with a geographical information system and a VR system and will have a speech interface. The duration is estimated to 5 years. The first prototype is 'Attack of mechanised infantry'. The conception model is pictured in Figure 7A.4. The ordering of the soldier is done through the ORD window shown in Figure 7A.5 (all window screen dumps are in Danish). Figure 7A.6 shows the screen the trainee sees. The map shows the area for the exercise and the position of the soldier and the armoured vehicle. The VRT window shows the group leaders view. The trainee can choose to stand still, walk or run. He can choose to do it standing up, ducking or crawling. His position is constantly shown in UTM co-ordinates, and a small window shows how long the simulation has been running.

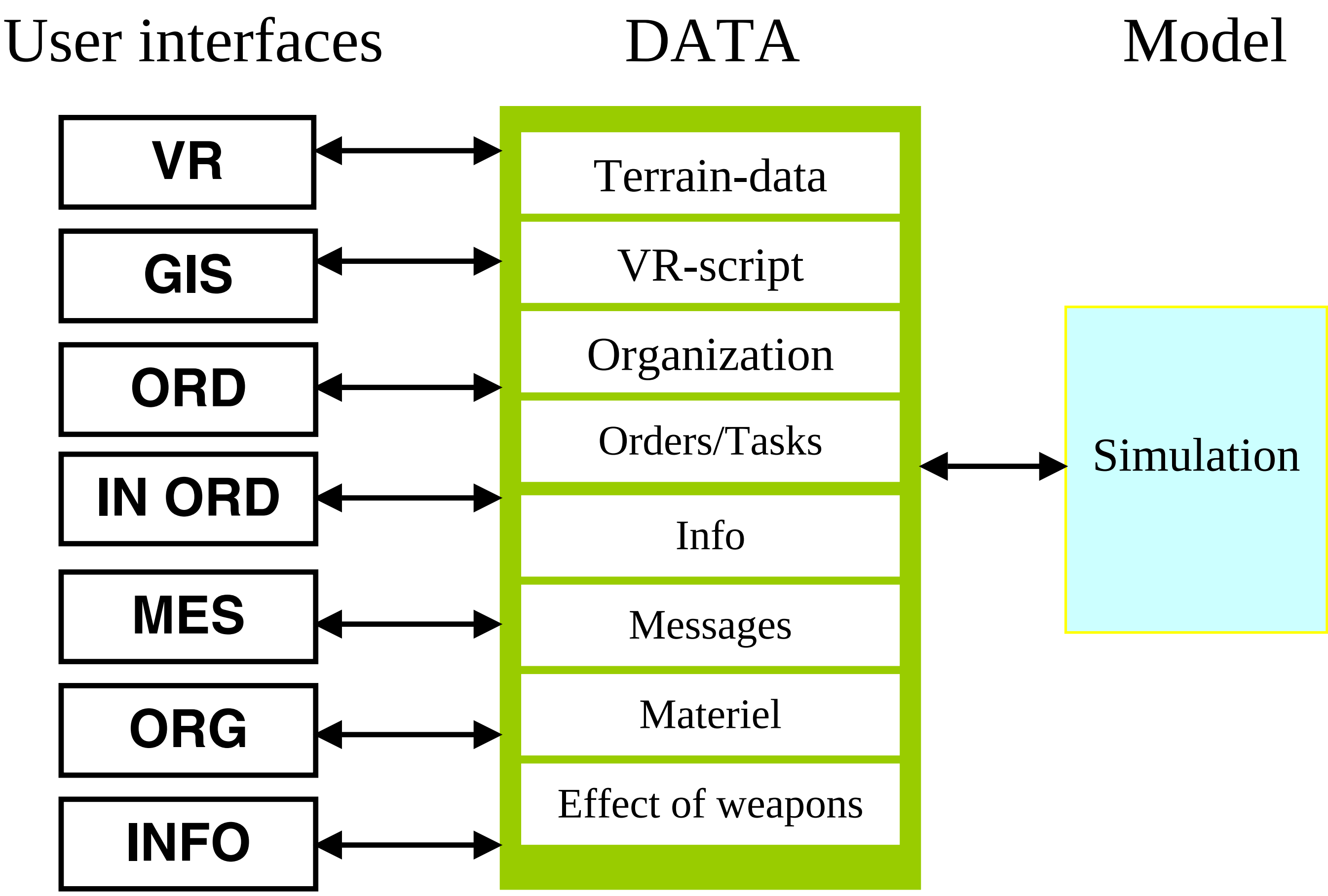

Figure 7A.4: Conceptual Model

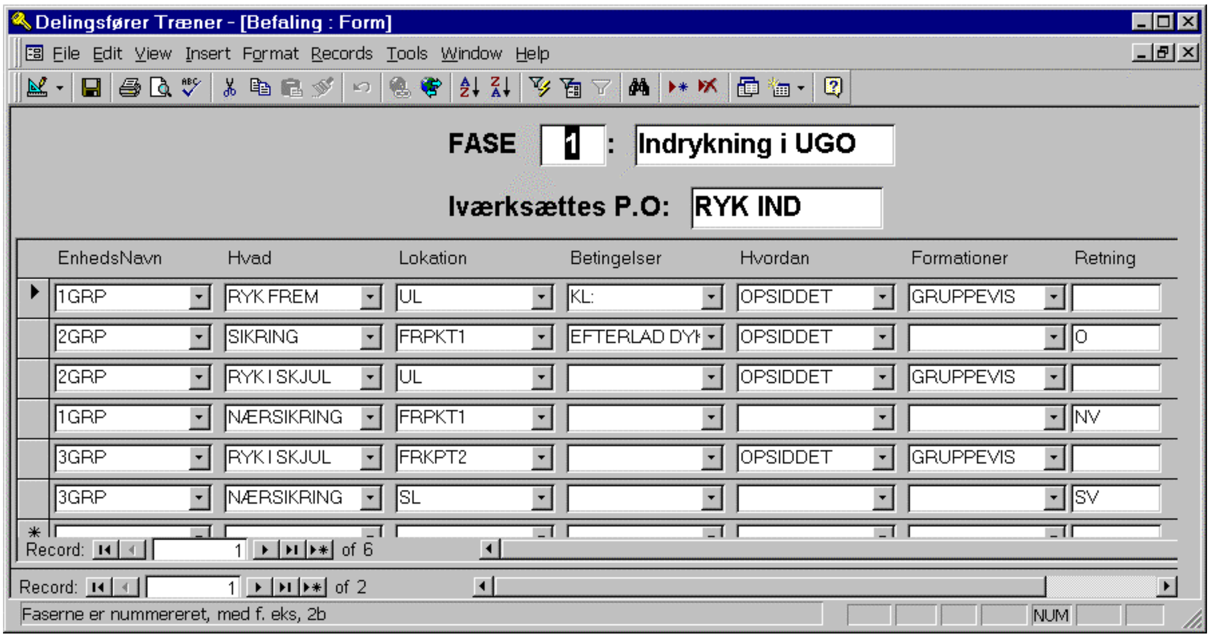

Figure 7A.5: The ORD window from the Tactical trainer for a group leader

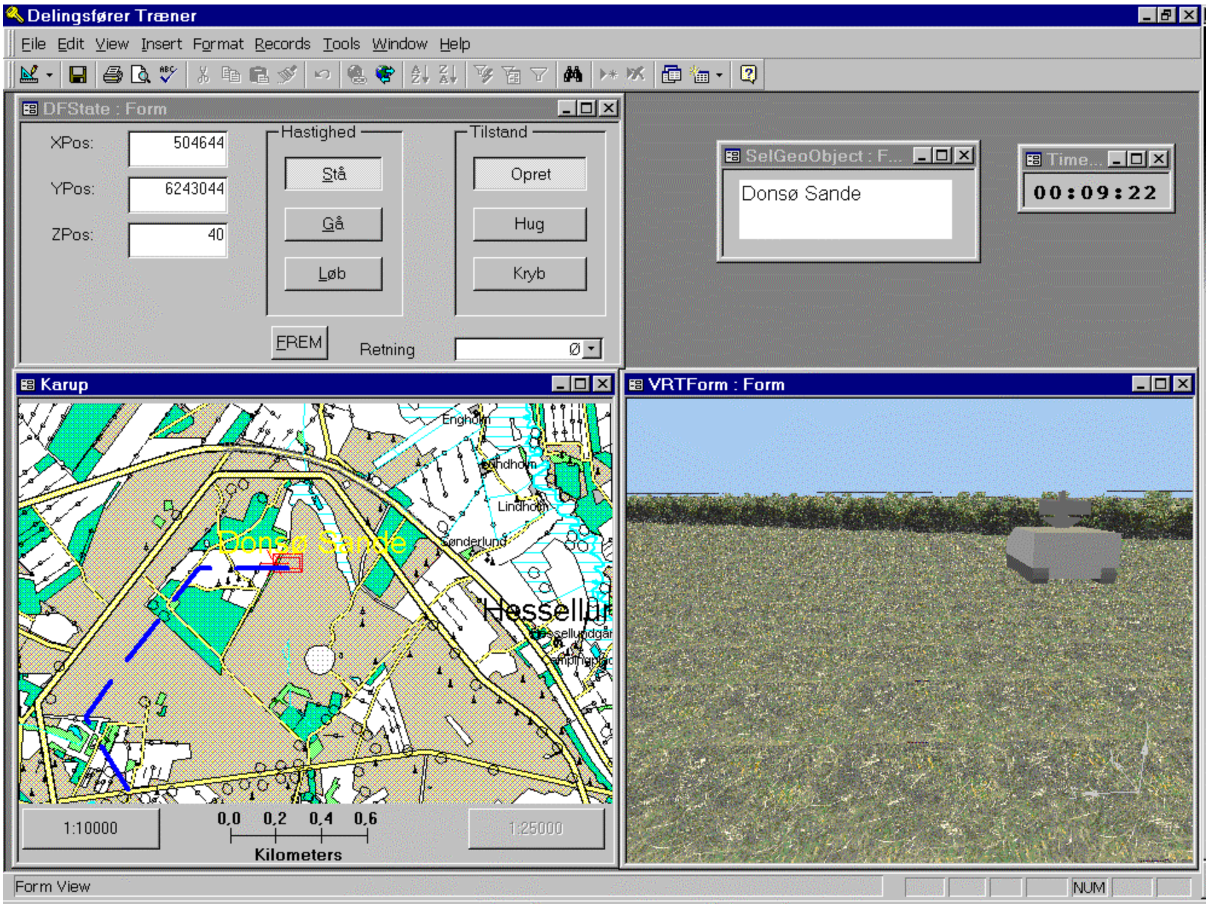

Figure 7A.6: Screen dump from the Tactical trainer for a group leader

F16 flight simulator is a readymade bought system from Hughes for the Airforce. It consists of a mock-up of a cockpit standing in front of 3 screens as shown in Figure 7A.7. The simulation is run on a Silicon Graphic's computer from a control room.

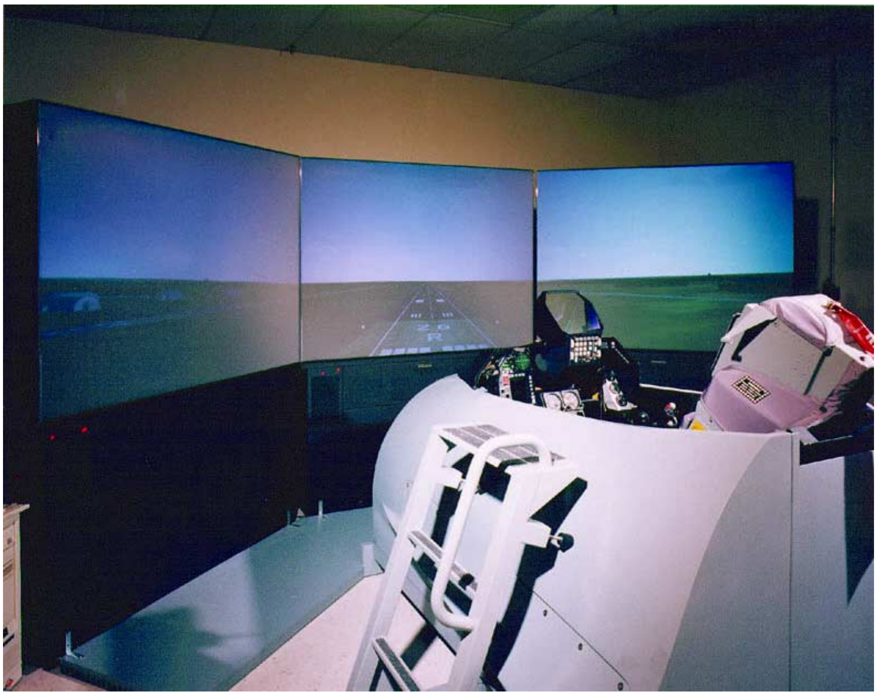

Figure 7A.7: F16 Flight Simulator

The Tank simulator is a readymade bought system from Siemens (NL) and Simtech (Israel) for the Army. It is for shooting and battle exercises for platoon and below. The simulator has 4 40-foot containers. 3 of the containers have a technician room, a leopard 1A5 DK mock-up, a local instructor control panel, and a leopard 2A5 DK mock-up. The last container has a technician room, a central instructor control panel, and a report room with 12 seats. The set-up is shown in Figure 7A.8 and Figure 7A.9 show a picture from one of the containers.

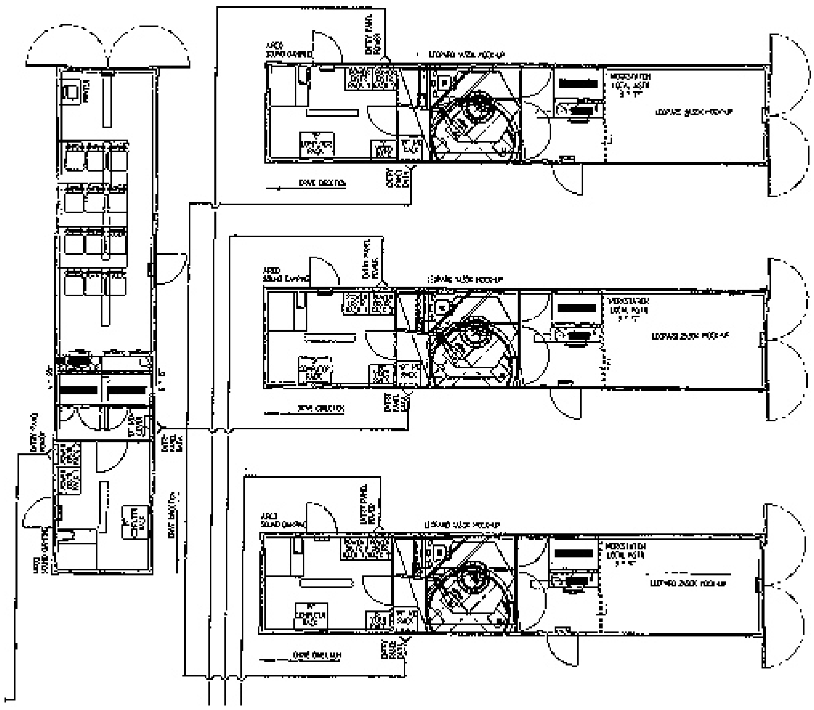

Figure 7A.8: Tank Simulator

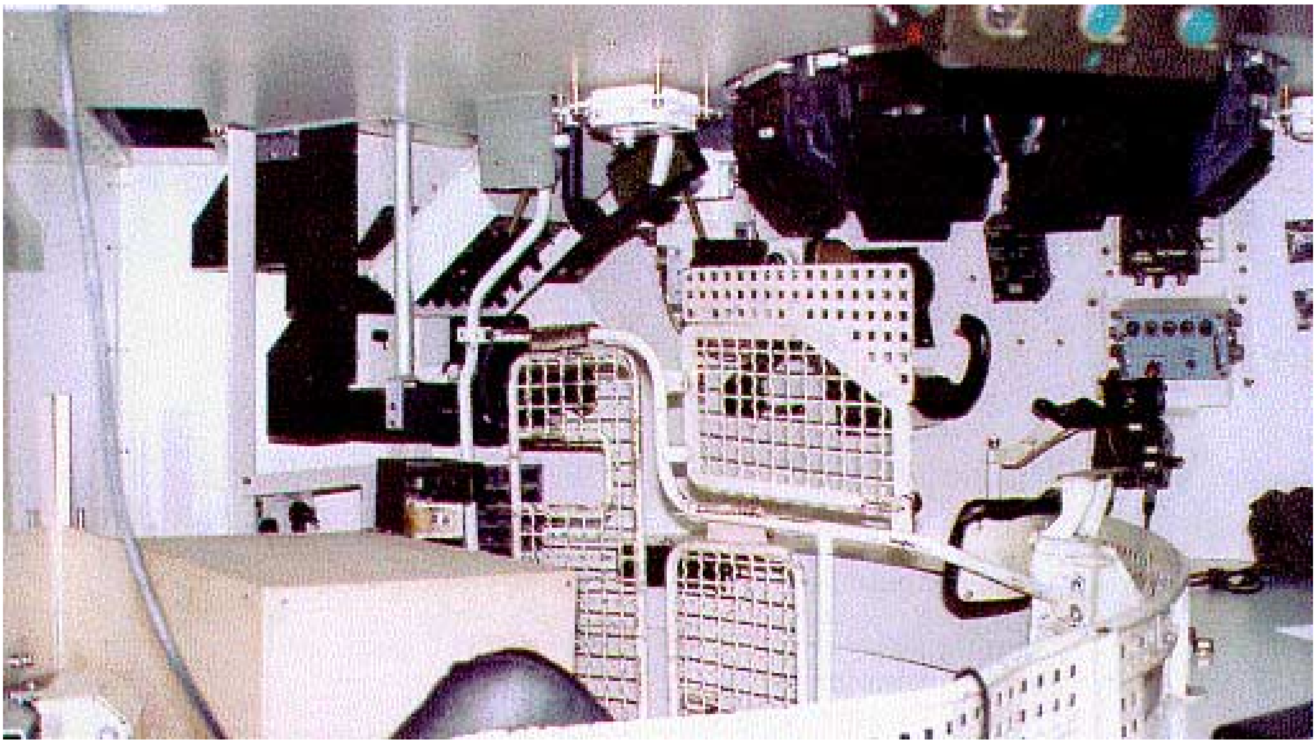

Figure 7A.9: Tank Simulator

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7B - Report on Virtual Reality in France

7B.1 Introduction

Les concepts et premières réalisations en Réalité Virtuelle datent maintenant d'un peu plus de 10 ans. Les solutions informatiques, matériels et logiciels, sont essentiellement d'origine anglo-saxonne. En France, seule la société Médialab proposait une solution alternative sous la forme du produit logiciel CLOVIS, développé à partir de 1990.

Depuis quelques années, de nombreuses entreprises ont développé des activités de Réalité Virtuelle : des groupes importants, comme Communications & Systèmes (ex CISI), SYSECA (groupe Thomson-CSF) ou le CEA (Commissariat à l'Energie Atomique), EADS (ex AEROSPATIALE MATRA), RENAULT, PSA Peugeot Citroën ; des petites et moyennes entreprises, comme IMMERSION SA à Bordeaux, SIMTEAM à Paris, ou VIRTUALYS à Brest ; des organismes publics, comme la DGA avec le CTSN et l'ETAS (Etablissement Technique d'AngerS), l'EDF (Electricité de France) ou la SNCF (Société Nationale des Chemins de Fer Français).

Plusieurs écoles dispensent désormais des formations diplômantes sur la simulation et la Réalité Virtuelle comme l'Institut Image ENSAM (Ecole Nationale Supérieure des Arts et Métiers) Bourgogne à Chalon-sur-Saône et l'ENIB (Ecole Nationale d'Ingénieurs de Brest) à Brest. D'autres incluent désormais cette matière sous forme de modules dans leur enseignement, par exemple l'ISTIA (Institut des Sciences et Techniques de l'Ingénieur d'Angers) pour les DESS Innov-Info et Innov-Europe (http://www.istia.univ-angers.fr/), la faculté d'Angers pour le DESS IOSI (Ingénierie en Optoélectronique, Signal et Imagerie) (http://www.univ-angers.fr/) et l'Ecole Navale de Brest.

La recherche n'est pas en reste : plusieurs laboratoires de facultés se sont dotés de moyens informatiques permettant de réaliser des travaux d'études ou des développements dans le domaine, comme le LRP (Laboratoire de Robotique de Paris), le labo de Philippe Fuchs à retrouver, et, bien sûr, l'INRIA (Institut National de Recherche en Informatique et Automatique) sur ses cinq sites de Grenoble, Nancy, Rennes, Rocquencourt (région parisienne) et Sophia-Antipolis (région de Nice). Un groupe de travail a été créé, le GT RV, sous le patronage de l'INRIA, dont la manifestation la plus récente a vu le rapprochement du GT RV avec son équivalent britannique, le VR-SIG, lors des journées des 11 et 12 juillet 2000 à Brest.

De grandes manifestations ont permis de promouvoir l'intérêt de cette discipline : IMAGINA à Monte-Carlo (Monaco) qui devrait malheureusement disparaître en 2001 faute de sponsors, « Interfaces des mondes réels et virtuels » à Montpellier, disparue en 1998, et «Laval-Virtual » (URL : http://www.laval-virtual.org/) à Laval dont la première édition a eu lieu en 1999.

On peut également retrouver des sujets autour de la Réalité Virtuelle dans des salons comme le MICAD, qui se tient tous les ans à Paris, et dans les conférences DSC (Driving Simulator Conference) qui se tient tous les deux ans (la dernière ayant eu lieu en septembre 2000).

Sans être exhaustif, nous allons essayer de décrire ce qui se passe aujourd'hui en France dans le domaine de la Réalité Virtuelle.

7B.2 Military Research and Technology in France

La Délégation Générale pour l'Armement (DGA) a pour rôle d'assurer la crédibilité des Forces Armées Françaises en leur fournissant des matériels hautement performants et conformes à leurs besoins opérationnels. Elle se veut également être, au cœur de l'Europe de l'armement, un acteur reconnu dans la préparation, l'architecture et la fourniture de systèmes de défense.

Un de ses axes stratégiques concerne la préparation du futur. Cet axe s'appuie sur un document de référence, le Plan Prospectif à 30 ans (PP30) qui réunit les éléments nécessaires pour orienter les actions de recherche. Ce document est donc l'outil principal pour orienter les études amont (EA) et les études technico-opérationnelles (ETO) et est lui-même alimenté par les résultats des EA et des ETO.

Les travaux de recherche sont donc financés par les Services de Programmes via les EA et les ETO. Un des organismes de la DGA, la Direction des Centres d'Expertise et d'essais, doit être une force de proposition pour les services de programmes et un partenaire des industriels qui réaliseront ces études.

La distinction entre recherche militaire et civile ne peut donc plus se faire. La recherche du meilleur compromis coût/efficacité implique l'utilisation potentielle de technologies civiles.

7B.3 Délégation Générale pour l'Armement (DGA)

7B.3.1 Centre Technique des Systèmes Navals (CTSN)

Le Centre Technique des Systèmes Navals (CTSN) de Toulon a utilisé le logiciel CLOVIS de la société Médialab pour développer un simulateur permettant d'étudier le comportement d'un hélicoptère sur le pont d'un navire soumis à la houle. L'utilisation de la simulation permet d'éviter la prise de risques en grandeur réelle. Les différentes composantes à étudier y sont fidèlement représentées : données géométriques du bâtiment et de l'hélicoptère, déformations de la mer dues à la houle.

Figure 7B.1 : Bâtiment sur une mer dynamique

Figure 7B.2: Hélicoptère en phase finale d'apponto

Figure 7B.3: L'hélicoptère sur le bâtiment

Le CTSN travaille également à la réalisation en simulation d'un navire virtuel aussi complet que possible en intégrant un grand nombre de simulations. Ils travaillent aujourd'hui sur les aspects vulnérabilité, lutte incendie et stabilité avant et après avarie. Dans un proche avenir, ils étudieront aussi les aspects intégration du système de combat sur la plate-forme. Le but ultime est de pouvoir suivre un programme naval avec un prototype virtuel qui évoluera tout au long du programme et de permettre l’accès aux différents intervenants du programme sur les aspects simulations et le couplage de ces dernières entre elles dans un environnement réaliste.

7B.3.2 Etablissement Technique d’AngerS (ETAS)

L’ETAS a utilisé plusieurs logiciels pour la réalisation de simulateurs en Réalité Virtuelle :

- DVs de PTC-Division,
- CLOVIS de Médialab,
- World Toolkit de EAI-Sense8,
- VEGA de CA-Paradigm.

DVs a été utilisé pour la réalisation d’essais pour caractériser l’immersion dans un environnement virtuel. Une thèse a été rédigée par Thierry Morineau en octobre 1996 à ce sujet.

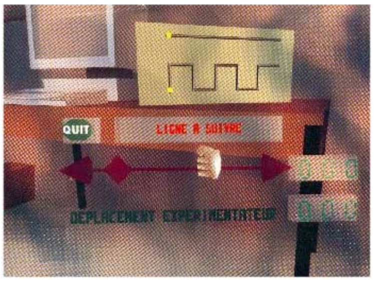

Figure 7B.4 : Expérience en immersion

CLOVIS a été utilisé pour la réalisation d’un environnement virtuel pour la simulation. Cet environnement a permis la mise en place et l’utilisation d’un simulateur permettant de téléopérer un robot à partir des interfaces réelles.

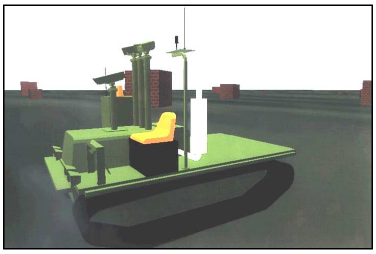

Figure 7B.5: Robot téléopéré dans l'environnement virtuel de simulation

World Toolkit a été utilisé pour la réalisation :

- d'un démonstrateur de vol sous voilure. Il s'agissait de voir comment les technologies de Réalité Virtuelle pouvaient être appliquées à l'apprentissage :

Figure 7B.6: Démonstrateur de vol sous voilure

- d'un démonstrateur pour l'apprentissage à la détection de mines :

Figure 7B.7: Détection de mines

- D'un simulateur de mobilité de véhicules terrestres, développé par la société SERA :

Figure 7B.8: Simulateur de mobilité

VEGA a été utilisé pour la réalisation d'un démonstrateur de vidéo-téléopération d'un char pour l'ouverture de brèches.

Figure 7B.9: Char démineur téléopéré

Figure 7B.10: Vues du téléopérateur

D'autres utilisations de VEGA sont envisagées dans un avenir proche, en particulier pour le simulateur SISPEO, simulateur d'études reconfigurable.

Dans le cadre de ses activités, l'ETAS utilise également la réalité augmentée intégrée dans un véhicule chenillé pour l'aide à la conduite.

Figure 7B.11: Véhicule de démonstration PISE

Figure 7B.12: Réalité augmentée à bord de PISE

7B.4 Grands groupes industriels

7B.4.1 Renault

Renault dispose d'un RealityCenter™ pour ses études sur le design de ses futurs véhicules.

Le Groupe de Recherche Simulateur de conduite et Réalité Virtuelle de la Direction de la Recherche a équipé un simulateur de conduite (conformateur avec des réglages ergonomiques) avec un casque de Réalité Virtuelle (Kaiser Proview 60) en 1999. Cette équipe est également le chef de file du projet européen Eureka n° 1924, CARDS, depuis 1998. Ce projet vise à l'étude et au développement d'un simulateur avec plate-forme et siège mobiles et casques de Réalité Virtuelle avec large champ de vision. Ses partenaires dans ce projet européen sont Hydraudine, Pons, SEOS, la société turque Infotron (spécialisée en Réalité Virtuelle), ainsi que le TNO/FEL et le CNRS/LPPA (Laboratoire de Physiologie de la Perception et de l'Action) - Collège de France plus particulièrement chargés de l'étude des capteurs de position et de la fidélité de la perception du mouvement.

Figure 7B.13: Vue conducteur. © Renault

Figure 7B.14: *Conformateur* ergonomique de Renault. © Renault

Renault travaille aussi sur le projet P2V (« Présentation Virtuelle de Véhicules »). Le champs d'application du projet est assez étendu, puisqu'il s'adresse à des clients internes tels que la Direction Marketing, la Direction du Design Industriel et la Direction de l'Ingénierie Véhicules. Le projet est basé sur l'utilisation des technologies de la réalité virtuelle pour la visualisation d'un véhicule complet sur station de travail ou grand écran. Ces technologies permettent une visualisation interactive et naturelle d'un véhicule, en image 3D avec relief et calculs temps-réel. L'utilisateur de l'outil est immergé dans le véhicule virtuel comme s'il était assis à l'intérieur d'une vraie voiture. Des capteurs de position à 6 degrés de libertés permettent un interaction naturelle, si l'utilisateur tourne la tête à gauche, l'image sera instantanément mise à jour pour refléter sa nouvelle position. Le projet est découpé en 3 sous-projets, tous basés sur les mêmes technologies et les mêmes outils, mais dédiés à des applications différentes :

- P2V Commercial : outil de présentation virtuelle de la gamme Renault dans les points de vente ;
- P2V Peinture : simulation réaliste des teintes et effets d'aspect de la peinture, utilisant des outils de rendu 3D temps-réel et interactifs ;
- P2V Architecture : prototypage virtuel appliqué aux avant-projets et à la conception des véhicules, utilisant également les technologies de visualisation 3D interactive.

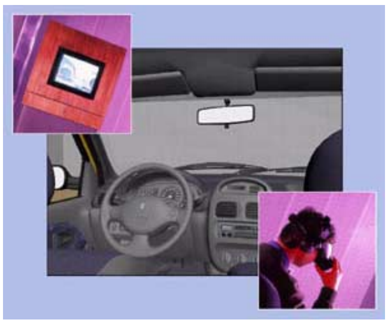

Figure 7B.15: Projet P2V. © Renault

URL : http://www.experts.renault.com/kemeny/index.html

7B.4.2 Groupe Peugeot Citroën (PSA)

Chez **PSA PEUGEOT CITROËN**, on peut visiter la nouvelle Xsara Picasso grâce à une application de réalité virtuelle. Une fenêtre virtuelle (ou Windows VR, à gauche de la Figure 7B.16) permet au visiteur de se déplacer autour de la Xsara Picasso ou de prendre place à bord du véhicule.

Figure 7B.16: Visualisation et interaction avec la XSARA Picasso de Citroën. © PSA

L'écran tactile permet au visiteur de naviguer de menus en menus et de déclencher un ensemble d'événements visuels et sonores qui sont autant d'éléments de découvertes du véhicule. En désignant la porte du bout du doigt, il peut l'ouvrir ou la fermer. Le client potentiel peut ainsi configurer la voiture selon ses souhaits, couleur de robe et des garnissages intérieurs, options, etc… Un capteur fixé sur la Windows VR repère sa position en permanence et recalcule en temps réel l'image 3D correspondant au nouveau point de vue du visiteur.

Cette application illustre les apports de la réalité virtuelle pour l'étude et la vente de véhicules.

URL : http://www.citroen.fr

Peugeot a développé une architecture de simulateur en Réalité Virtuelle immersive appelée SHERPA. L'objectif principal était de réaliser une immersion fonctionnelle du conducteur dans un environnement virtuel en vue d'analyser sa tâche de conduite et en pouvant mener des études sur les fonctions du véhicule. La stratégie de développement autour de la Réalité Virtuelle permettait d'une part de pouvoir évaluer ces technologies prometteuses, et d'autre part, de permettre des échanges entre les différents acteurs de l'entreprise.

Trois versions de SHERPA ont été installées dans différents sites du groupe. Basées sur la même architecture, ces trois versions ont été optimisées en fonction du besoin des équipes du site, en particulier reconfigurabilité pour l'un des sites et capacité de mener des études ergonomiques pour un autre.

Les travaux actuels portent sur l'immersion sonore du conducteur pour des sources liées au véhicule (bruits liés au moteur et à la transmission, bruits d'équipements, bruits des passagers, …), pour des sources liées aux interactions du véhicule avec son environnement extérieur (roulement, aérodynamique, chocs avec les mobiles du trafic ou des infrastructures routières, pluie, …) et pour des sources liées à l'environnement (ambiances sonores diffuses ou localisées, mobiles du trafic, météo, …).

Figure 7B.17: Simulation de conduite en réalité virtuelle immersive - simulateur SHERPA. © PSA

7B.4.3 Aerospatiale Matra (maintenant EADS)

L'établissement de Méaulte (80), l'un des quatre sites de production en France chargé notamment de la fabrication des pointes avant des Airbus, disposait de trois applications des technologies de Réalité Virtuelle au sein d'Aérospatiale pour les produits Airbus et Ariane :

Revue de projet - visualisation et annotation.

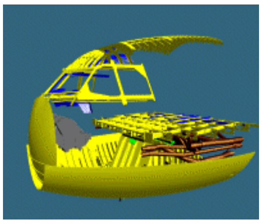

Figure 7B.18: Assemblage des composants de l'AIRBUS A340.

Visualisation, simulation et validation des assemblages des composants de la pointe avant de l'Airbus A340 dont l'Etablissement de Méaulte est en charge de la fabrication

Image fournie par Aérospatiale - 10/05/99

© Aérospatiale.

Support de formation pour la maintenance.

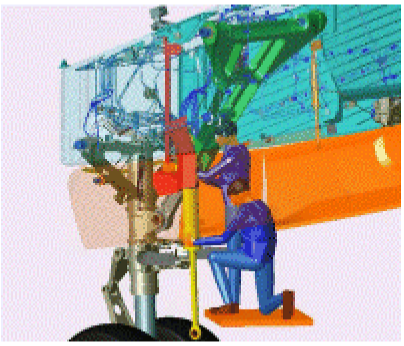

Figure 7B.19: Opérations de maintenance d'un AIRBUS.

Simulation des opérations de maintenance du train d'atterrissage d'un Airbus pour le support de formation. Ici l'avatar (personnage virtuel) permet de visualiser les différentes opérations.

Image fournie par Aérospatiale - 10/05/99

© Aérospatiale.

Animations d'aide à la vente.

Simulation en temps réel du tir n° 4 de la fusée Ariane 5 et du largage d'un satellite.

Ces trois exemples ont été réalisés par Aérospatiale avec le logiciel dVise de Division, filiale de Parametric Technology. Ils illustrent parfaitement les trois principaux champs d'application des technologies de Réalité Virtuelle que sont la simulation et la validation de grands assemblages avec la détection de risque de collision, la réalisation de supports de formation et la réalisation d'animations pour la présentation du projet au client.

URL : http://www.eads-nv.com/ (mais on n'y retrouve pas ces applications).

7B.4.4 SYSECA (groupe Thomson-CSF)

SYSECA, filiale de Thomson-CSF, est une société de services en ingénierie informatique. L'offre de SYSECA comporte deux volets principaux :

- L'intégration de systèmes (gestion et technique),
- L'infogérance et la maintenance.

SYSECA a capitalisé et intégré 7 ans de recherche et de développement dans le domaine de la simulation visuelle 3D Temps-Réel dans un studio de développement d'application de Réalité Virtuelle appelé EO, une technologie construite sur des standards du marché : architectures SGI sous IRIX™ (avec le support total des salles immersives RealityCenter™ et CAVE™), PC sous Windows™ (bientôt Linux) et librairie graphique Open GL. L'offre autour d'EO se compose de U-Man (module de visualisation de corps humains avec peau élastique et cinématique inverse pour l'ergonomie et l'étude gestuelle réaliste), O-Cad (module d'extraction de composantes géométriques depuis un nuage de points pour la reconstruction de surfaces paramétriques NURBS), A-Car (module de rendu réaliste destiné aux études de style automobiles permettant l'utilisation directe de données de CAO) et I-Phi (ensemble de techniques de rendu haute fidélité pour la simulation physiquement exacte de phénomènes optiques). L'offre de SYSECA porte sur le conseil et les études (réalisation d'études de concepts et de systèmes dans le domaine de la Réalité Virtuelle) et l'intégration et le support (conception, développement et maintenance de systèmes de Réalité Virtuelle).

Une adaptation du logiciel U-Man a été réalisée récemment pour l'entraînement de l'équipe française de natation synchronisée (qui n'a pas eu le temps de l'utiliser pour la préparation des JO de Sydney). Le développement fait partie d'un projet plus important liant SYSECA au Ministère de la Jeunesse et des Sports en vue d'intégrer des technologies récentes dans les programmes d'entraînement sportif. Cette collaboration a déjà eu lieu par le passé pour modéliser en simulation Temps-Réel des courses nautiques comme l'America's Cup.

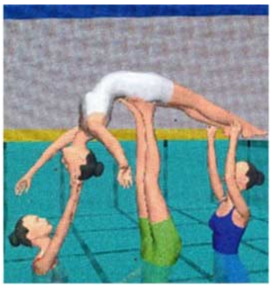

Figure 7B.20: U-Man swimmer © Syseca

Figure 7B.21: l'ISS. © Syseca

URL : http://www.syseca.thomson-csf.com/simulation/

7B.4.5 Communication et Systemes (CS)

Cette entreprise, en rachetant la CISI, a utilisé les compétences de cette dernière pour proposer de nouveaux développements en Réalité Virtuelle.

Ainsi, outre les travaux réalisés avec le CEA, la SNCF (voir le paragraphe correspondant), Renault et le CNES (Centre National d'Etudes Spatiales) (application : simulateur en Réalité Virtuelle de la station spatiale internationale), la CISI a participé au développement d'un démonstrateur marketing pour le véhicule Xsara pour PSA. Ce développement permet à un acheteur potentiel du véhicule de pouvoir visualiser différentes couleurs de carrosserie, d'ouvrir le coffre, les portières, de regarder à l'intérieur.

Un autre projet appelé Visions, développé sur la base de leur librairie interne pour le développement d'applications de Réalité Virtuelle VERTIGO, devrait permettre à l'horizon 2002, de simuler une maquette de film, de pièce de théâtre ou de publicité. Initié par le département Réalité Virtuelle de CS, et financé par la Communauté Européenne, le projet a été lancé en janvier 2000. En collaboration avec des partenaires européens (la société anglaise CREATEC pour la modélisation des acteurs virtuels, la société suisse Artemedia pour la bibliothèque d'objets 3D), l'outil Visions doit permettre de créer et de simuler en 3D et en Temps-Réel les acteurs, les décors, les éclairages, les caméras d'une scène.

URL :

http://www.visions4d.com pour le projet Visions ;

http://www.c-s.fr/ pour la société CS (mais pas d'informations sur la réalité virtuelle).

7B.5 Groupes Nationaux

7B.5.1 EDF

Depuis 1993, la Division recherche et Développement d'EDF étudie la valeur ajoutée de la Réalité Virtuelle pour, entre autres, tester différentes solutions de maintenance, assister les intervenants lors de la réalisation et former des opérateurs. En particulier, les bureaux d'ingénierie ont recours au capteur laser SOISIC/3Dipsos pour constituer des bases de données 3D copiant fidèlement les installations réelles. Les formateurs, quant à eux, définissent aujourd'hui les nouveaux outils pédagogiques à base de Réalité Virtuelle, incluant l'animation de mécanismes complexes, la visualisation de phénomènes physiques, la mise en action de processus abstraits, … Cette technologie est calibrée pour chaque population d'utilisateurs : formation en groupe sur grand écran, casques immersifs, périphériques adaptés…

Un projet récent VISIT, visite virtuelle des centrales nucléaires, est développé avec les technologies de réalité virtuelle. Il permet de montrer l'invisible (voyage au cœur de la fission), l'inaccessible et d'immerger les visiteurs dans les environnements habituellement fermés au public (découverte de la zone contrôlée d'une centrale nucléaire). VISIT est utilisé dans les Centres d'Information du Public qui accueillent les visiteurs de centrales EDF, et lors d'expositions internationales, de salons et de conférences.

7B.5.2 SNCF

La SNCF ne développe pas d'applications de Réalité Virtuelle à proprement parler. La Direction de la Recherche a par contre travaillé en collaboration avec des sociétés de service pour réaliser un certain nombre de projets utilisant ces technologies.

Une plate-forme a été développée pour évaluer les apports de la Réalité Virtuelle. Elle se compose d'une « boîte à outils » réutilisable et d'une base pouvant accueillir divers types d'applications dans le domaine ferroviaire. Une première version, développée avec la CISI (avant son rachat par CS), avait pour cadre la Gare du Nord. Dans un environnement réaliste, reconstitué sur la base de plans, photos et films vidéo, l'utilisateur interagit avec la simulation. L'objectif était de permettre d'étudier les apports de la Réalité Virtuelle dans les domaines de l'aide à la conception, à l'aménagement, à l'amélioration des services clients, à la formation, à la maintenance… Sur cette base, un projet de test de signalétique pour la gare Magenta a été développé ensuite où des clients, choisis dans un panel représentatif de voyageurs, ont dû effectuer un parcours à l'intérieur de la gare.

La Direction de la Recherche poursuit ses investigations dans le domaine et a demandé à l'Ecole des Mines de Paris de réaliser un simulateur pour l'apprentissage de la sécurité lors de la maintenance des voies ferrées (voir plus loin).

7B.6 Laboratoires de recherche

7B.6.1 INRIA

Fortement impliqué dans l'informatique graphique depuis de nombreuses années, l'INRIA développe à travers plusieurs équipes de ses cinq sites situés à Grenoble, Nancy, Rennes, Rocquencourt et Sophia-Antipolis, des projets de recherche, des méthodes et des outils trouvant des débouchés dans de nouveaux secteurs de la recherche, de l'industrie, de la santé ou des médias.

La réalité virtuelle est l'un des cinq grands défis scientifiques que l'INRIA a défini dans son plan stratégique pour les cinq prochaines années et qui sont :

- maîtriser l'infrastructure numérique en sachant programmer, calculer et communiquer sur Internet et sur des réseaux hétérogènes ;
- concevoir les nouvelles applications exploitant le Web et les bases de données.

<u>Concevoir et maîtriser l'automatique des systèmes complexes</u>

Les sociétés développées reposent sur la conception et la production d'objets et de grands systèmes de plus en plus complexes : la complexité est maintenant intrinsèque aux objets considérés individuellement (automobiles, avions civils ou militaires, téléphones, télévisions, ordinateurs, robots, satellites, chacun de ces objets étant lui-même un assemblage de composants variés), et aux systèmes qu'ils constituent (constellations de satellites, systèmes de défense, systèmes manufacturiers, systèmes de transports).

(…) Le « prototypage » et la réalité virtuelle qui permettent de modéliser des « objets », de les simuler et in fine de les faire fonctionner sans les fabriquer, seront les méthodologies de base de la conception des produits industriels. Des difficultés techniques considérables devront encore être surmontées pour mettre au point les chaînes de conception « tout intégrées » du futur, qui combineront la CAO, des modèles de simulation et d'optimisation de formes et de validation des résultats, des interfaces multimodales efficaces et naturelles, et la conception des logiciels embarqués.

<u>Combiner simulation et réalité virtuelle</u>

Il s'agit de construire des systèmes regroupant analyse d'images, modèles numériques, synthèse d'images et automatique, autour de plates-formes expérimentales à hautes performances, avec l'objectif de développer des simulations temps-réel, de permettre des interactions sensorielles, de comprendre les problèmes de modélisation multi-échelles et, pour la conception, de pouvoir optimiser.

L’investissement de l’INRIA dans la réalité virtuelle

La priorité accordée à la réalité virtuelle se traduit sur le terrain par un investissement à plusieurs niveaux :

7B.6.1.1 *Création de budgets spécifiques*

A l’initiative de la direction scientifique, pour le développement de travaux à fort impact dans le cadre des actions de recherche coopératives (ARC) telles que GREVE, plate-forme de réalité virtuelle, 3D-MEG, modélisation géométrique et physique de l’activité cérébrale et AISIM, simulateur pour la chirurgie. Ces actions favorisent les collaborations pluridisciplinaires et associent des équipes extérieures ;

7B.6.1.2 *Acquisition et mise en œuvre opérationnelle de plates-formes réalité virtuelle de très haut niveau dans le cadre de plusieurs unités de recherches :*

- Ecrans cylindriques immersifs (RealityCenter™) dans les unités de recherche Irisa/INRIA de Rennes, INRIA Rhône-Alpes à Grenoble :

  - un triple écran en arc de cylindre (4m de rayon) d'une largeur de 9m à 12m et d'une hauteur de 2,70m à 3.50m;
  - trois projecteurs Barco ;
  - un supercalculateur SGI Onyx2 InfiniteReality2, avec de 6 à 8 processeurs, et de1 à 3 cartes graphiques ;
  - un dispositif d'affichage en relief CrystalEyes de Stereographics avec lunettes à obturateur à cristaux liquides ;
  - un environnement audio spatialisé (3 à 8 canaux).

- Le premier plan de travail virtuel (Workbench) a été installé en France à l’INRIA Rocquencourt. Il comporte :

  - un calculateur Onyx 2 (SGI) avec 4 processeurs et 2 cartes graphiques (IR2) ;
  - un système de visualisation, commercialisé par la société TAN (Allemagne) comprenant :

    - 2 écrans perpendiculaires de 1.10m sur 1.80m chacun et deux projecteurs vidéo tri-tubes ;
    - un dispositif d’affichage en relief CrystalEyes de Stereographics avec lunettes actives à obturateurs à cristaux liquides ;
    - un système d’enregistrement des mouvements de la tête permettant une observation de la scène sous différents angles en fonction des déplacements de la personne ;
    - un stylo à 6 degrés de liberté Fastrack de Polhemus.
    - Ces acquisitions font l’objet d’une aide financière des collectivités territoriales (région, département) ;

7B.6.1.3 *Poursuite de projets* et mise en œuvre de nouveaux projets de recherche mettant en jeu la réalité virtuelle : SIAMES, iMAGIS, ISA, i3D et EPIDAURE ;

7B.6.1.4 *Soutien aux projets* utilisateurs de la réalité virtuelle : ROBOTVIS, PRISME, SHARP, MOVI, MIRAGES, BIP, PARIS, MACS, VISTA et SAGA ;

7B.6.1.5 *Soutien à la création d’entreprises* utilisant notamment les technologies développées à l’INRIA : REALVIZ (trucage numérique et animation d’images de synthèse) issue du projet ROBOTVIS à l’INRIA Sophia Antipolis, et Neoxy (simulation graphique 3D) issue du projet ISA à l’INRIA Lorraine. Ces deux start-ups ont bénéficié de l’aide d’INRIA-Transfert, incubateur de l’INRIA spécialisé dans le secteur des sciences et technologies de l’information et de la communication (STIC).

7B.6.1.6 *Mise en réseau des plates-formes réalité virtuelle INRIA de l'Hexagone*

Il est prévu de relier, par une liaison à 2,5 Gbits, les plates-formes réalité virtuelle de Rennes et de Grenoble (voir projet iMAGIS) ainsi que le plan de travail virtuel (Workbench) implanté à Rocquencourt (voir projet I3D). Cette interconnexion va permettre de réaliser des environnements virtuels coopératifs rendant possible à plusieurs utilisateurs distants de visualiser et d'interagir sur une même maquette numérique. La mise en œuvre de l'interconnexion doit prendre forme courant 2000.

Le dossier de presse « Réalité Virtuelle » 2000 en français de l'INRIA présentant le détail des projets en cours peut être trouvé à l'URL :

http://www.inria.fr/Presse/rv-fra.html

En parallèle, un groupe de travail sur la Réalité Virtuelle a été créé en 1994 sur l'initiative de trois chercheurs. Il s'est donné comme but de fédérer les efforts de recherche des équipes universitaires et industrielles françaises travaillant dans les différents domaines d'application de la réalité virtuelle. Depuis, le groupe de travail réalité virtuelle a notamment permis de créer une vaste communauté scientifique française en couvrant des domaines tels que simulation (architecture, environnement extérieur, chirurgie, robotique, etc.), réalité augmentée, téléopération, travail coopératif et interface homme-machine.

Le groupe de travail organise des journées qui comprennent des exposés, démonstrations et visites. Ces journées (dont la septième session a eu lieu les 3 et 4 juin 1999 à Laval dans le cadre de la manifestation *Laval-Virtual*) ont rencontré depuis cinq ans un succès croissant. Elles ont permis de présenter des exposés de très haut niveau scientifique et technique et de montrer (souvent en avant-première) des applications concrètes dans le domaine industriel.

Le Groupe édite une lettre électronique d'informations, *RÊVERIES*, qui permet de maintenir un contact permanent entre les participants du groupe de travail. *RÊVERIES* publie notamment des propositions de thèses, de post-doctorats et d'emplois dans le domaine de la réalité virtuelle. La revue compte à ce jour (avril 2000) plus de 150 abonnés après 89 numéros.

Tous les numéros de RÊVERIES sont disponibles sur le site Web de Karl Tombre (Loria INRIA Lorraine) à l'URL :

http://www.loria.fr/~tombre/VirtReal/maillist.html

Depuis 1997, le groupe de travail réalité virtuelle est co-animé par Jean-Luc Dugelay (EURECOM, Sophia Antipolis) et Gérard Subsol (Projet EPIDAURE, INRIA Sophia Antipolis) à l'URL :

http://www-sop.inria.fr/epidaure/GT-RV/gt-rv.html

7B.6.2 Ecole des Mines de Paris

Le Centre CAO & Robotique assure au sein de l'Ecole des Mines de Paris une double mission d'Enseignement et de Recherche.

Le Centre assure les enseignements suivants :

- Option Robotique en seconde et troisième année du cycle ingénieur,
- Cours d'automatique en tronc commun,
- Enseignement spécialisé optionnel de Réalité Virtuelle,
- DEA "Méthodes Informatiques des Systèmes Industriels", filière "**Systèmes Robotiques Avancés**", commun avec l'Université de Versailles Saint Quentin.

Le Centre de CAO & Robotique accueille une dizaine de doctorants et autant d'étudiants de DEA et conduit des travaux de recherche avec un fort partenariat industriel autour des thèmes suivants :

- Techniques de la réalité virtuelle et réalité augmentée,
- Modélisation et commande des systèmes mécaniques,
- Automatisation des transports routiers,
- Vision,
- Modélisation géométrique et CAO,
- Nanorobotique.

Objectifs généraux de l'équipe Réalité Virtuelle et Réalité Augmentée

Les axes de recherche de l'équipe portent principalement sur "l'interfaçage comportemental" de l'homme dans un monde virtuel (ou mixte réel/virtuel), en exploitant au mieux des comportements naturels de la personne. Celle-ci doit être immergée au niveau sensorimoteur et aussi au niveau mental. Notre méthodologie de conception d'un système RV demande à être approfondie sur le plan technique et sur le plan psychologique grâce à des collaborations entreprises cette année avec des ergonomes et des psychologues. Les solutions réalisées sont testées en particulier dans trois applications :

Interfaçage comportemental

Cet axe de recherche a fait l'objet de différentes collaborations industrielles, dont :

- L'étude du comportement de consommateurs dans un magasin virtuel breveté pour l'entreprise INVIVO, spécialisée dans les études de marché. Le premier magasin vient d'être terminé en 1999 et va être exploité commercialement début 2000. Des tests ont permis de vérifier et de valider la cohérence de l'immersion et de l'interaction naturelles du consommateur dans ce magasin virtuel.

- l'exploitation de la réalité virtuelle pour la conception de véhicules (études entreprises avec PSA Peugeot Citroën, et Sommer Allibert). L'objectif est de réduire le temps de conception grâce à la diminution du nombre de prototypes réels.

A ce titre, nous faisons partie du Réseau de Recherche à finalité théorique *Modèles du sujet pour la conception*, dont le responsable scientifique est Pierre Rabardel, professeur de psychologie à l'Université de Paris VIII.

La formation des opérateurs à des interventions sur les infrastructures ferroviaires en réalité virtuelle.

Cette étude fait l'objet d'une thèse CIFRE avec La Direction des Recherches de la SNCF.

La réalité virtuelle permet d'apporter de véritables potentiels là où certaines formations échouent. Il s'agit donc de déterminer le degré d'immersion et d'interaction nécessaire à un apprentissage et à son transfert en fonction des objectifs de la formation. L'outil pédagogique créé pour le formateur permet non seulement d'immerger le formé dans un environnement reproduisant la réalité mais aussi d'exploiter les diverses fonctionnalités de la réalité virtuelle. Le sujet de thèse est principalement orienté vers la création et l'expérimentation d'un agent intelligent HAL (Help Agent for Learning) basé sur les techniques d'intelligence artificielle, permettant au formateur d'exploiter différents scénarios de formation.

Anciens travaux

Les travaux avec la DER d'EDF sur l'amélioration de l'immersion d'un téléopérateur. Pour augmenter sa téléprésence visuelle, nous utilisons la vision stéréoscopique permettant une meilleure perception tridimensionnelle de la scène observée. La problématique d'immersion d'objets virtuels dans une scène réelle a été abordée pour proposer à l'opérateur une "réalité augmentée". Les recherches d'une thèse portent sur la physiologie de la perception de la profondeur en vision stéréoscopique pour améliorer l'ergonomie des interfaces visuelles stéréoscopiques, en collaboration avec le CERMA (Centre d'Etudes et de Recherches de Médecine Aérospatiale).

URL : http://caor.ensmp.fr/Fr/Recherche/RV-RA/team.html

7B.6.3 LRP

Le Laboratoire de Robotique de Paris (**LRP**) est un laboratoire public de recherche des Universités de Paris 6 et de Versailles St-Quentin. Le LRP est une unité associée au CNRS (URA 1778), rattaché au département Sciences pour l'Ingénieur (**SPI**).

Le LRP a été créé en 1987 et s'est installé dans ses locaux actuels (1200 m²) sur le campus de l'Université de Versailles, site de Vélizy-Villacoublay, en 1993. Il comporte un effectif d'environ 60 personnes constitué par une trentaine de permanents (enseignant-chercheurs, chercheurs et personnel administratif) et d'une trentaine de thésards. Il abrite un Centre de Ressources Technologiques, le CRIIF, par lequel il réalise la promotion de certains résultats de recherche et envisage leur transfert.

Le LRP regroupe dans une même entité à la fois mécaniciens, automaticiens et informaticiens pour aborder des projets de recherche ambitieux en robotique.

URL : http://www.robot.uvsq.fr/

Le principal domaine de compétence du **CRIIF** est la **ROBOTIQUE**, domaine où se combinent des systèmes dynamiques pluridisciplinaires faisant appel à :

- la mécanique,
- l'automatique,
- l'informatique en temps réel,
- l'infographie.

Le **CRIIF** est un Centre de Ressources en Technologies (CRT) adossé au laboratoire de Robotique de Paris (LRP). Le label de CRT est un label délivré par le Ministère de l'Education Nationale de la Recherche et de la Technologie (Direction des Technologies). Il garantit l'aptitude du centre à travailler sur la base d'obligations contractuelles, le respect des délais, des coûts et de la confidentialité.

Pour étendre son domaine d'intervention, le CRIIF s'associe également de manière ponctuelle des compétences prises dans d'autres établissements de recherche et d'enseignement de la région Ile-de-France comme :

- l'IUT de Vélizy : Département Génie des Télécommunication et des Réseaux,
- l'IUT de Cachan : Département Génie Electrique et Informatique industrielle,
- le Laboratoire de Robotique de l'Université d'Evry (LRE),
- l'Institut de Physique Fondamentale de l'Université d'Orsay.

Le CRIIF travaille en relation étroite avec des sociétés d'ingénierie robotique.

CRIIF : Centre de Robotique Intégrée d'Ile de France
10, 12 Avenue de l'Europe - F.78140 VELIZY VILLACOUBLAY
Tél. : (+33) 01 39 25 49 62 - Fax : (+33) 01 39 25 47 31

URL : http://www.robot.uvsq.fr/criif/sommaire/domaine/domaine.htm

Les techniques de Réalité Virtuelle sont utilisées dans le Laboratoire pour une utilisation en téléopération. Philippe Coiffet, auteur de plusieurs livres sur la Réalité Virtuelle en français, fait partie du LRP.

7B.6.4 ACROE

L'ACROE est un centre de recherche du Ministère de la culture et de la communication.

C'est aussi une équipe du Laboratoire CLIPS de l'Institut IMAG-Grenoble.

Elle a été fondée en 1976 à l'INPG (Institut National Polytechnique de Grenoble) par : **Claude CADOZ, Annie LUCIANI, Jean-Loup FLORENS.**

Ses travaux, qui diffusent dans tout le domaine des Réalités Virtuelles, portent principalement sur l'Informatique et la Création Artistique, et en particulier : **Musique & Image Animée**

Ils ont des applications dans d'autres domaines technologiques : robotique, télécommunications, éducation, industries

Quatre types d'activités :

- Recherche scientifique et technique,
- Formation scientifique et culturelle,
- Création artistique : musique, image animée, danse …
- Diffusion de produits : industries culturelles, technologiques.

Trois finalités :

- Publication scientifiques,
- Objets multimédia : images, sons…
- Outils technologiques : logiciels, matériels, plates-formes…

L'ACROE est fondatrice de la méthode de synthèse en images et en sons, appelée aujourd'hui Synthèse par modèle physique. Elle a introduit le principe de la synthèse multi-sensorielle modulaire et du contrôle gestuel à retour d'effort.

URL : http://www-acroe.imag.fr/

Un des produits de l'ACROE est CORDIS-ANIMA, un moteur de simulation de phénomènes dynamiques.

Les comportements dynamiques peuvent être des ***déplacements*** et ***déformations*** mécaniques, que l'on peut **entendre** à l'aide d'un haut-parleur, **voir** par l'intermédiaire d'une image animée affichée sur un écran **toucher** et percevoir par les mains par l'intermédiaire d'un système gestuel à retour d'effort.

7B.7 Formations diplômantes

Les mastères spécialisés sont une formation de haut niveau, à orientation professionnelle, proposée par les Grandes Ecoles de management et d'ingénieurs réunies au sein de la Conférence des Grandes Ecoles. Depuis 1986, le Mastère spécialisé (M.S.) est un label attribué à des formations spécifiques de niveau Bac+6.

7B.7.1 ENIB

Un mastère spécialisé en Réalité Virtuelle Distribuée (RVD) est organisé par l'Ecole Nationale d'Ingénieurs de Brest (ENIB) en coopération avec l'Institut d'Informatique Industrielle (3xi) dans l'environnement industriel et universitaire du Technopôle Brest-Iroise (TBI).

En partenariat pédagogique avec le CNRS, l'ENSAI, ENSTB, l'Ecole des Mines, St Cyr Coëtquidan, l'IRISA et le GT-RV, les Universités de Genève, de Glamorgan et de Constantza et des collaborations industrielles avec la DCN, l'IFREMER, le CNET, Silicon Graphics, Thomson T&S, Virtualys et CS, le contenu des cours recouvre la synthèse d'images et les univers virtuels, les IHM immersives, la simulation et l'animation Temps-Réel, la modélisation des comportements, la réalité augmentée, la réalité virtuelle distribuée, les aspects matériels, les bibliothèques 3D/Multimédia, les systèmes auteurs. Différents intervenants industriels présentent leurs réalisations au cours de conférences et de travaux pratiques. La conduite de projet est également abordée, ainsi que les aspects de design industriel en réalité virtuelle. Le Laboratoire d'Informatique Industrielle permet également de travailler sur un projet de recherche : AréVi/oRis, plate-forme logicielle pour la réalité virtuelle distribuée.

URL : http://www.enib.fr/

7B.7.2 Activité Image - ENSAM

L'activité Image propose un mastère spécialisé en simulation et Réalité Virtuelle.

Le but est de former des chefs de projets capables de maîtriser les concepts et les technologies de gestion dynamique d'images numériques. Le programme pédagogique est orienté vers des connaissances théoriques très spécifiques à la gestion de ces images et favorise l'utilisation de ces technologies. Les étudiants devront être capables d'analyser un développement de simulation de visuel ou de trucage numérique, et de mettre en place des moyens techniques et humains pour l'aboutissement des projets.

En partenariat pédagogique avec l'INA (Institut National de l'Audiovisuel), Silicon Graphics, l'ENSAM (Ecole Nationale Supérieure des Arts et Métiers) de Cluny et des intervenants extérieurs industriels, le contenu des cours recouvre les aspects de développement (langages C et C++, Open GL), la robotique, le son numérique, la vidéo, le stockage informatique, l'infographie 3D, les trucages numériques, la CAO et la gestion de projets.

Une des réalisations marquantes des étudiants concerne un simulateur d'abattage de bois destiné à un lycée forestier en Bourgogne (France) : ARVESTER (Abattage Reconstitué Virtuellement En Synthèse Temps-Réel), présenté en 1997 au salon IMAGINA.

A l'occasion des soutenances des étudiants, l'Activité Image organise depuis trois ans maintenant des « Rencontres de la Réalité Virtuelle » sous la forme de débats ouverts, en partenariat avec des industriels, et de présentations d'applications industrielles.

L'Activité Image a le projet de se doter, en plus des moyens déjà à sa disposition, d'un système CAVE. Ce projet devrait aboutir en fin de l'année 2000.

URL : http://www.ai.cluny.ensam.fr/

7B.8 Implication des collectivités locales

7B.8.1 Laval

La ville de Laval organise depuis deux ans maintenant une manifestation intitulée « Laval-Virtual ». La première édition a été faite sous le patronage du GT-RV de l'INRIA, déjà évoqué.

L'ambition de la ville de Laval est de devenir un pôle français de la Réalité Virtuelle.

En plus d'organiser cette manifestation, la ville de Laval s'est récemment équipée d'un RealityCenter™ appelé « Ingénierium », inauguré la 24 février 2000 par le Président de la République Française.

En particulier, la ville de Laval s'est dotée d'un RealityCenter™. Avec l'Ingénierium, le centre de Réalité Virtuelle de Laval met à la disposition des entreprises un équipement unique en Europe par sa taille. On ne trouve pas d'équivalent en France. Véritable instrument de travail collaboratif, l'Ingénierium associe le réalisme d'une visualisation en relief à grande échelle et la souplesse d'un travail en Temps-Réel ; il permet ainsi des applications de revue de projet et de simulation interactive. D'autre part, grâce à la puissante configuration de la plate-forme avec un écran géant et images en relief, il est aussi un nouveau vecteur de communication, particulièrement efficace, au service des fonctions marketing et commerciale.

Les clients de l'Ingénierium se comptent parmi les industriels (automobile, aéronautique, chantiers navals, mécanique, plasturgie, …), les architectes et les urbanistes, les organismes de formation, les concepteurs d'applications ludiques ou culturelles, les agences de communication, les sociétés de service en infographie, interactivité et simulation, et, d'une façon générale, toute entreprise amenée à utiliser l'image 3D interactive pour le développement de ses activités.

Outre les moyens matériels, l'Ingénierium dispose de solutions logicielles pour la CAO (CATIA d'IBM et EUCLID de Matra Datavision), pour l'infographie 3D (Studio d'Alias/Wavefront), pour la simulation (VEGA de CA-Paradigm).

La vocation de l'équipe en charge de l'Ingénierium n'est pas de développer des applications spécifiques mais bien de mettre à disposition le moyen. Les développements se font via des sociétés de service en informatique dont certaines sont déjà implantées à Laval.

L'Ingénierium est sous la responsabilité de CLARTE (Centre Lavallois de Ressources Technologiques) qui offre, en plus de la mise à disposition de l'outil, une large palette de services : bureaux d'accueil équipés et connectés, salle de réunion, assistance à l'utilisation et conseils sur mesure, organisation de conférences et de dîners-débats, aide à la création d'entreprise, développement d'applications spécifiques par des sociétés partenaires présentes sur le site, commercialisation des prestations proposées par les entreprises partenaires…

CLARTE est également impliqué dans des projets européens, en particulier celui du développement du CUBE, système CAVE™ démontable et déployable sur demande.

Pour les développements spécifiques nécessitant des travaux de recherche, CLARTE est associée avec l'IRISA/INRIA de Rennes, qui dispose également d'un RealityCenter™.

URL : http://www.clarte.asso.fr/

7B.9 Sociétés impliquées dans les développements de la Réalité Virtuelle

7B.9.1 Immersion SA

Immersion SA est une société créée en 1994. Elle est basée en région Aquitaine et Parisienne. Cette société a choisi d'importer et de distribuer des produits destinés à la technologie de la Réalité Virtuelle ainsi que de procéder à l'ingénierie de simulateurs spécifiques.

Elle est présente dans les principaux marchés suivants : éducation, recherche, aéronautique, défense, architecture, génie civil et services commerciaux et financiers.

Parmi les domaines d'applications, on citera les exemples suivants :

- Design industriel,
- Conception avancée d'ensembles mécaniques,
- Robotique,
- Formation à la maintenance,
- Simulation de conduite,
- Gestion de réseaux informatiques,
- Visualisation de cotations boursières,
- Simulation de flux,
- Formation médicale,
- Visite de monuments inaccessibles ou disparus.

Immersion SA a acquis la confiance de grands groupes industriels ainsi que celle des centres de recherche et des laboratoires comme par exemple : Aérospatiale, CS, CEA Fontenay aux Roses, Centre d'essais en vol, Actionel, Ifremer, Thomson Optronique, DCN Brest, DCN Toulon, SERA, Art3000, Renault centre de recherche, Syseca, Dassault Aviation, CNET France Telecom, CCETT, INA, EDF/DER, Linelec, Serviware, Arcimage, DGA/ETAS, SNCF Direction de la Recherche, Sanofi Recherche, Matra Cap Systèmes, CNRS IRIT, CRIIF, MiraLab Université de Genève, Université de Montpellier, Université de Lille, …

URL : http://www.immersion.fr/

7B.9.2 SimTeam

SimTeam, créée en 1998, est une société de services et d'ingénierie en informatique proposant des prestations de conseil, de veille technologique, de développement d'applications logicielles et de vente de matériel utilisant les nouvelles technologies graphiques interactives : Réalité Virtuelle, simulation, outils d'aide à la vente, maquette numérique. SimTeam propose également une large gamme de matériels de Réalité Virtuelle : capteurs magnétiques, lunettes stéréoscopiques, systèmes à retour d'efforts, gants de données, visiocasques, …

Cette société, filiale de Virtual Presence, a travaillé en particulier avec la DGA/ETAS sur le développement de l'application d'apprentissage à la détection de mines en utilisant le logiciel World Toolkit et le bras à retour d'efforts Phantom.

Quelques références de la société : DGA, Renault, EDF, France Telecom, Schneider Electric, Lectra Systems, IFP, InVivo, le CNRS, l'INRIA.

URL : http://www.simteam.com

7B.9.3 Virtualys

Virtualys est une S.A.R.L. au capital de 50500 F créée le 1er Juillet 1997 au sein du Technopôle Brest-Iroise. Cette entreprise est implantée dans les locaux de l'Ecole Nationale d'Ingénieurs de Brest

(E.N.I.B.). Elle a pour objet social : "**l'ingénierie, l'industrialisation et la commercialisation de systèmes de Réalité Virtuelle.**".

Cette société réunit 17 associés dont 13 professeurs de l'E.N.I.B. . Elle emploie un ingénieur diplômé de l'E.N.I.B., Jean-Luc Mathieu (Jean-Luc.Mathieu@virtualys.com).

URL : http://www.virtualys.com.

7B.9.4 OKTAL SA

OKTAL a été créée en 1989 à Toulouse. Spécialisée dans la simulation et l'image de synthèse, OKTAL a une connaissance approfondie de la méthodologie et des techniques de simulation destinées à l'entraînement, à l'étude ou à la validation de systèmes, devenant un acteur performant du marché de la simulation, auprès d'industriels et de comptes étatiques, civile ou militaires. Les divers projets d'études et de réalisation menés pour le compte de la défense, et les nombreux contacts entretenus tant avec les responsables de simulateurs qu'avec les opérationnels confèrent à OKTAL une grande connaissance dans ce domaine.

OKTAL possède à ce titre une double compétence matériel et logiciel acquise dans des secteurs de haute technologie, principalement dans les domaines des logiciels graphiques, de la simulation Temps-Réel et de la génération de scènes numériques 3D, lui permettant ainsi de prendre en charge tout ou partie d'un système complet hard/soft.

Le savoir-faire d'OKTAL lui a permis d'être référencé comme fournisseur auprès d'industriels tels que Thomson, EADS, Matra, SAGEM, Dassault.

OKTAL a travaillé avec la SNCF pour la réalisation d'un simulateur d'études et de recherches ferroviaires appelé SIMUFER, avec Peugeot pour la réalisation de leur simulateur SHERPA (voir paragraphe Peugeot) et avec la DGA/ETAS pour améliorer le simulateur de vol sous voilure.

Spécialisé dans la simulation multi-senseurs, OKTAL fait partie du Solution Group mis en place par CA-Paradigm autour de la solution logicielle VEGA.

URL : http://www.oktal.fr/fr/a_simulation.htm

7B.9.5 Euphonia

Euphonia est la première société spécialisée en France de consultants en acoustique virtuelle. Créée en 1995, Euphonia explore les nouvelles ressources offertes par l'acoustique virtuelle dans le domaine d'activité de ses clients.

Euphonia commercialise la gamme de produits Lake. Elle fait bénéficier ses clients de ses liens avec les centres de recherche ainsi que de son expertise dans le domaine architectural, de la psychoacoustique et du traitement du signal. Euphonia assure une veille technologique dans le domaine des techniques de l'audio-spatialisation et organise régulièrement des journées d'étude sur ce thème.

URL : http://www.euphonia.fr/

7B.9.6 REALVIZ

REALVIZ is bringing significant new innovations to the world of video, film and computer graphics by providing revolutionary new software tools that dramatically reduces the time required to produce high-quality computer-generated images, animation and 3D models.

The company has introduced new dimensions to 2-D image processing by providing the missing link between traditional live action and 3-D computer generated animation.

REALVIZ dispose, grâce aux technologies développées par l'INRIA, de la capacité mathématique à « virtualiser le réel ». Cette capacité technique est traduite au travers des produits logiciels suivants :

ImageModeler : photo-modélisation - modélisation d'objets 3D à partir de photos.

MatchMover : mélange réel/virtuel automatique dans des séquences d'images.

Stitcher : création d'images panoramiques de haute définition.

URL : http://www.realviz.com/

7B.9.7 PROLEXIA

Fondée en 1994, la société PROLEXIA propose des solutions de modélisation et de simulation innovantes basées sur l'utilisation de techniques avancées telles que la Réalité Virtuelle, les langages d'acteurs, l'Intelligence Artificielle et la propagation de contraintes.

Ces solutions sont construites par enrichissement de composants logiciels puissants (modules Intelligence Artificielle, interpréteurs, graphiques 2D/3D, simulateur, communication) développés en interne ou par des partenaires et permettant de réduire les coûts de développement et d'améliorer la maintenabilité des applications développées.

La société a développé en particulier le produit ADVANSYS, un outil de modélisation et de simulation 3D orienté objet. PROLEXIA a en particulier travaillé pour la DCN (Direction des Constructions Navales) Ingénierie Sud pour le projet de démonstrateur SAD (Système d'Arme de Dissuasion) et pour le GESMA pour un outil de visualisation tactique 2D et 3D pour 'laide à la chasse aux mines.

URL : http://www.prolexia.fr

7B.9.8 ACTIONEL

ACTIONEL intègre la Réalité Virtuelle au sein de ses études d'ingénierie de la conception.

Dans les processus d'investissements industriels, ACTIONEL intervient dans la conception de modèles représentant des systèmes complexes, notamment pour l'aide à l'exploitation, à la maintenance, à la modification (modernisation) et au déclassement (démantèlement) d'installations. Par exemple dans le secteur nucléaire ou pour les plates-formes industrielles, ACTIONEL intègre la Réalité Virtuelle dans le « cycle de vie » d'un investissement industriel, à la fois sur le plan technique (nouveaux concepts, nouveaux outils, nouvelles interfaces), mais également sur le plan méthodologique (nouvelles démarches, nouvelles métaphores).

Exemples d'applications :

- En collaboration avec ALPHATEM, étude de faisabilité de l'implantation physique d'un procédé dans un bâtiment existant. L'utilisation des techniques de Réalité Virtuelle (sur grand écran ou avec des casques de Réalité Virtuelle), a permis aux différents intervenants de mieux appréhender l'impact de l'implantation de nouveaux équipements dans leur environnement ;

- Avec la COGEMA, validation de la conception d'une boîte à gants. Ces boîtes sont conçues pour aider un opérateur humain dans ses manipulations de substances toxiques avec une sécurité maximale. L'utilisation de la Réalité Virtuelle a permis de remplacer une maquette réelle à l'échelle 1 par son équivalent en images de synthèse interactives et de valider ou invalider les choix technologiques ou ergonomiques ;

- Simulation de sources radioactives. Afin de préparer des opérations de maintenance ou de démantèlement dans le milieu nucléaire, ACTIONEL a réalisé une simulation des « nappes de radiations » émises par des sources actives. Un opérateur peut alors s'entraîner, dans le monde virtuel, à des opérations dans l'environnement avec une meilleure perception des risques potentiels.

URL : http://www.actionel.com/

7B.9.9 DUONS SYSTEMES

Duons Systèmes, groupe spécialisé dans la maîtrise des risques des systèmes, met en œuvre la technologie de Réalité Virtuelle adaptée à la simulation 3D interactive, à travers les compétences de son unité spécialisée VIRTUEL 3D. Cette unité développe depuis plusieurs années, sur base PC-Windows et avec le logiciel Superscape, des projets de simulation 3D interactive principalement dans les secteurs de la défense, du transport aérien et terrestre, des télécommunications et de l'industrie manufacturière.

Le groupe DUONS SYSTEMES propose d'accompagner ses clients dans l'aide à :

- l'avant-vente ;
- la conception ;
- la validation ;
- la formation et à la maintenance ;
- la vente.

Les principales références en simulation 3D interactive sont Alcatel ISR, Citycom, Cité des Sciences et de l'Industrie, DCN ingénierie, DGAC - SEFA, Educinfo, Ecole Nationale d'Equitation, Gaz de France - SAIG, IDMS, Ministère de la Jeunesse et des Sports, Progipro, Sinapse, Tulip Compute.

7C - Report on Virtual Reality (VR) in Germany

Thomas Alexander
Research Establishment for Applied Sciences (FGAN)
Research Institute for Communication,
Information Processing, and Ergonomics (FKIE)

The new and innovative technologies of Virtual Reality (VR) and Virtual Environments (VE) show a lot of promising benefits for a variety of diverse applications. Nevertheless, a lot of research is needed to come up with reasonable application. For this reason, today's VR is still a major research topic including the areas of information sciences, human factors, and psychology.

On the other hand, applications of VR have become more and more recently. Apart from using VR systems as pure presentation platforms, applications in the areas of rapid-prototyping and rapid-engineering exist today. Moreover, training of special tasks becomes possible with today's technology.

This report deals with both, research studies and industrial application, of VR in Germany. To limit the huge amount of studies and commercial products, the overview has been limited to high-end VR-systems. Desktop-VR and VRML-applications are not taken into account. Moreover, the area of the traditional (driving and flight) simulators has also been excluded from this survey.

The information used for this report has been collected by internet survey. That is to be as actual as possible. However, the rapidly ongoing progress in the VR-domain leads to new findings, which might not have been included. To minimize inaccuracies general information has been preferred for this report instead of specific project information.

7C.1 Military Research and Technology in Germany

Differently to other countries, the area of military research and technology is organized distributed and decentralized in Germany. Research and development projects are usually handled by the Federal Office of Defense Technology and Procurement (BWB), being the largest technical office in Germany. The BWB is basically responsible for all military projects and central point of contact for the industry. The main duties of the BWB are management of research and technology before development process, development, test, procurement, maintenance, and disposal of military technical material.

The BWB if funding research and development projects at subordinated institutions. These studies can be performed by universities, independent research institutions, and industrial companies. Further research funding of VR-projects is done by other federal authorities, e.g. the ministry of education and research or the industry.

A strict division into civil and military research studies cannot be done. Nonetheless, a lot of ideas and results from the civil domain can be used in the military domain and vice versa. This is especially true for a cost-intensive application like VR. For this reason this report includes all kind of VR-studies, no matter if they are civil or military, governmental or commercially funded.

7C.2 Categories of VR-Users

The area of VR-users and VR-projects can be divided into research studies and applications. Research studies handle VR as a topic itself and analyze specific functions of or related to a VR-system. These studies are usually carried out at academic establishments. Application of VR-systems mean to use the VR-systems as a tool in a (design, presentation) process. This area is usually dominated by industrial and service companies. Usually industry is end-user while service companies are developers of VR-systems.

The establishments carrying out research studies can be subdivided into universities and independent research establishments. Universities perform studies of fundamental research and the studies of independent research establishments are usually more application-oriented.

This structure is shown in Fig. 7C.1 and is used to categorize the research activities in VR and to facilitate a general overview.

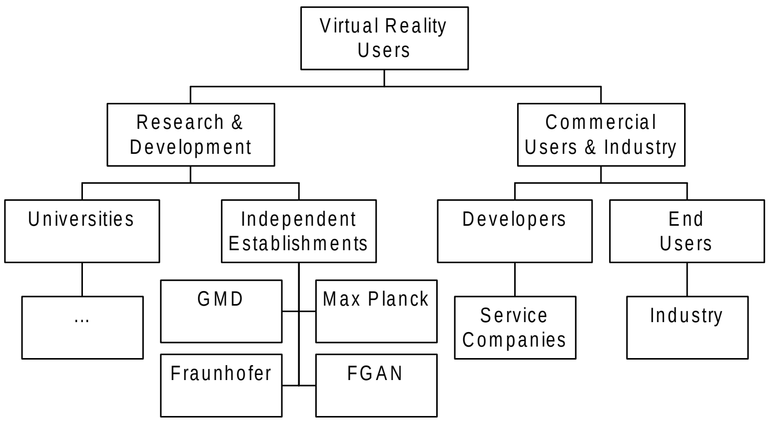

Fig. 7C.1: Structure of VR-Users as used further in this report

At the same institution different uses of VR are likely to occur. Especially presentation is often added to research or other uses in order to show the capabilities of a VR-system or visualize results of an analysis. In the following these uses will be clarified and a general overview about the state of the art will be presented.

7C.3 Research and Development

In the area of research and development in Virtual Reality a lot of studies exist. Moreover, because of the high costs of a VR-system, these systems are often used for more than one study making a clear separation in single projects impossible. Therefore this chapter summarizes the major institutions carrying out studies in this area. In this connection, important information about the institutions, their interests in VR and the main goals of their studies are described shortly.

For further information links to the establishment's UALs are added making internet surveys possible.

7C.3.1 Universities

The majority of fundamental research studies are carried out at universities. Therefore the results gained are of fundamental importance for the design of VR-systems. However, several studies are dealing with applied, specific problems.

This chapter summarizes the activities related to high-end VR of German universities.

7C.3.1.1 University of Stuttgart – High Performance Computing Center (HLRS)

The *High Performance Computing Center (HLRS)* of the *University of Stuttgart* supports users from Research and Development with high-end computer-technology and its application. The overall goal is to provide the academic users with hard- and software to support and facilitate research studies in various areas. The support consists of mathematical and numerical computing power and visualization capabilities.

For visualization a *Virtual Environments Lab* has been established. Shown in Fig. 7C.2 is the CUBE being the center of the *Virtual Environments Lab*. The CUBE is a stereoscopic back-projection system like a CAVE. In the CUBE the virtual scene is projected on three walls (each 2,5 m high) and the floor (2,8 m x 2,8 m). This way it facilitates a high degree of immersion into the scene. The graphic computing platform includes an Onyx2 Double Rack system with 3 Infinite Reality pipes. The system is connected to the HWW supercomputing platforms allowing interactive visualization of complex numerical models.

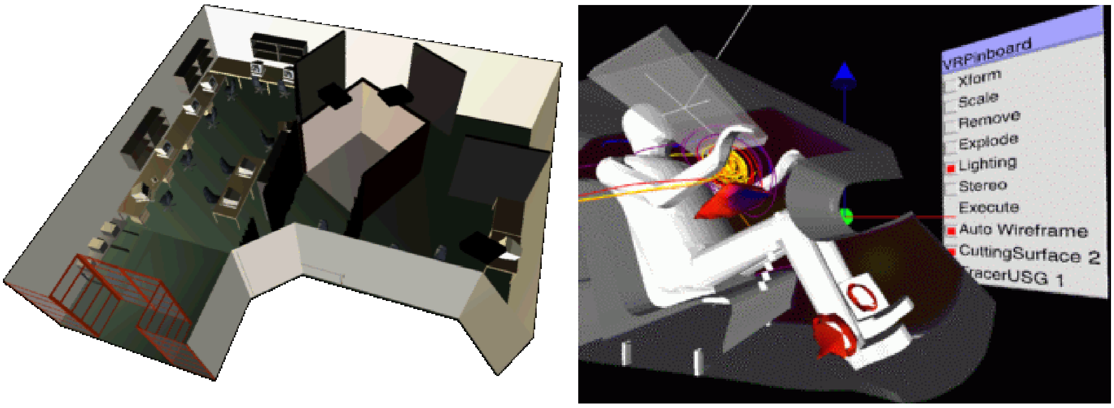

Fig. 7C.2: The CUBE and a VR application at the HLRS

For interaction different I/O-devices are present. They include different tracking-systems (Polhemus, Ascension), the Saitek tablet, Facespace Pinch Glove, PC-based devices, and the InWorld VR CyberWand joystick.

Actual projects are applications of VR-techniques for visualization and the development of a VR framework. The framework is called COVISE (COllaborative VIsualization and Simulation Environment) and allows integration of simulations, postprocessing, and visualization of functionalities in a virtual environment.

- Internet-sites:
  http://www.hlrs.de/
  http://www.hlrs.de/structure/organisation/vis/velab/

7C.3.1.2 Rheinisch-Westfälische Technische Hochschule Aachen – Computer Center

At the *Technical University of Aachen* VR-related topics are mainly carried out at the *Department of Virtual Reality and 3D-Visualization* of the *Computer Center*. It was decided to centralize these activities and establish a VR center with high-end computer infrastructure, because building up and supporting a VR-system is a very cost- and personal-intensive project. The resources of this center can be used by diverse faculties, e.g. the faculty of electronic engineering, computer sciences, medicine, architecture, and mechanical engineering.

At the moment the technical infrastructure consists of a SGI Onyx2 IR and several SGI O2s. As projection systems a self-developed HoloDesk-Workbench, Barko-Workbench, and Visual Research HMD are available. I/O devices like PHANToM, DataGlove, and motion tracking systems are also present.

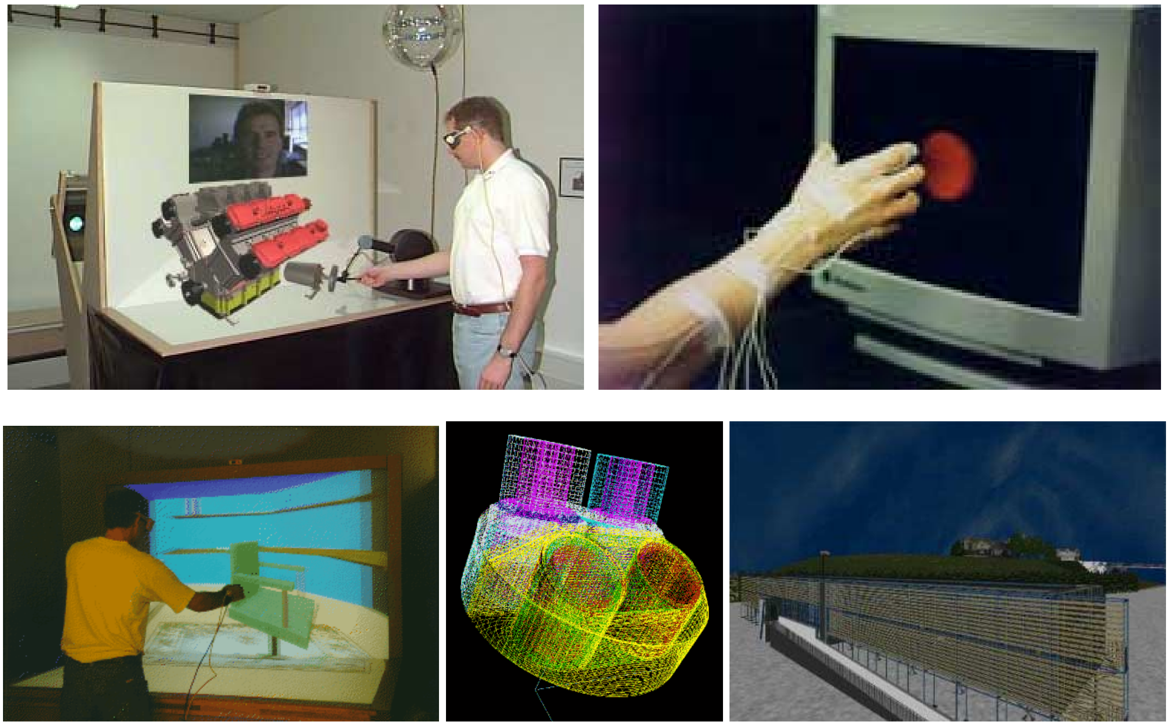

Fig. 7C.3: VR-Applications at the *VR department*: MAESTRO, IMPACT, HoloDesk, motor design, architecture

The department is cooperating with various institutes and faculties, especially including the *Faculty of Technical Computer Science*. Actual projects include interactive visualization of the airflow of a combustion engine, analysis of multi-modal interaction techniques including haptic feedback (MAESTRO), VR-based construction, and validation of mechanical kinematics, visualization of architecture, medical application of VR in the area of motion analysis (IMPACT) and remote VR using fast communication lines.

- Internet-sites:
  http://www.rz.rwth-aachen.de/
  http://www.rz.rwth-aachen.de/vr/

7C.3.1.3 University of Bielefeld – Technical Faculty

Topics in the area of VR are processed at the *Technical Faculty* of the *University of Bielefeld*. In this faculty the *Artificial Intelligence Group* runs a *Virtual Reality Lab*. The lab consists of a SGI Onyx2 IR graphic workstation, a responsive workbench, and a three-dimensional wall-size projection. A sample application in the lab is shown in Fig.7C.4.

The motivation of the artificial intelligence group is based on using knowledge-based systems and AI techniques to enhance intuitive communication between human and 3d-graphics. Later the activities were extended to VR-technology. Actual projects deal with the building of intelligent VR interfaces for highly interactive construction and design, which are supported by knowledge-based techniques.

Fig. 7C.4: *Virtual Reality Lab* of the *Artificial Intelligence Group* in Bielefeld

The overall goal of the research activities is to enhance multimedia-systems by means of including different text-modalities (text, speech, gesture). In this connection dynamic representation of knowledge and multi-agent systems for enhancing intelligent human-computer interaction are being analyzed. These topics are integrated into the processing of projects. They are widely dealing with design, construction, and interactive visualization.

- Internet-sites:
  http://www.TechFak.Uni-Bielefeld.DE/techfak/ags/wbski/
  http://www.TechFak.Uni-Bielefeld.DE/techfak/ags/wbski/labor.html

7C.3.1.4 Bergische Universität-Gesamthochschule Wuppertal – Safety of Transportation Systems

The *Chair of Safety of Transportation Systems* of the *Faculty of Safety Engineering* at the *University of Wuppertal* carries out research studies on motorcycle simulators. In the actual approach a motorcycle simulator has been developed using immersive VR. As shown in Fig. 7C.5, the mockup consists of a -real- motorcycle. This is done to facilitate haptic feedback. Visual simulation is realized using a full-immersive Head-Mounted display. The simulation includes digital binaural acoustic simulation and real-time driving dynamics for motorcycles.

Fig. 7C.5: Motorcycle-simulator using VR-technology at the *Chair of Safety of Transportation Systems*

The research studies include fundamental research in the area of depth perception with emphasis on the influence of stereoscopic viewing, requirements on the level-of-detail management in virtual simulation environments and concept of using the virtual motorcycle simulation for education and training.

- Internet-sites for further information:
  http://www-verkehr.uni-wuppertal.de/Welcome.html
  http://www-verkehr.uni-wuppertal.de/dirk/dirk.html

7C.3.1.5 Technical University of Darmstadt – Institute of Flight Mechanics and Cybernetics

At the *Institute for Flight Mechanics and Cybernetics* at the *University of Darmstadt* new applications of VR in design and training are analyzed. The main application area is aerospace.

For the design of a new aircraft a stereoscopic wall projection was found to be advantageous, because designers could view a layout commonly and discuss it in a group.

In the area of education and training of pilots a hybrid approach consisting of a traditional mockup and head-mounted display was analyzed. The approach uses a simple, variable, and adaptable hardware mockup of the cockpit to make force feedback possible. This way the operator is able to touch and feel panels of the cockpit layout. Sight simulation is done by an immersive head-mounted display. The correct visual simulation is calculated by a high-end graphic workstation. With this layout the use of the same cockpit-model for a variety of different cockpit layouts is possible with a minimum of modifications.

The practical usability of the system is being analyzed at the moment by means of trials. Nonetheless, the financial advantage of using this hybrid VR-cockpit instead of a real mockup has been proofed.

- Internet-sites:
  http://www.tu-darmstadt.de/fb/mb/fmr/Welcome_de.html

7C.3.1.6 Bauhaus University of Weimar – Computer Science in Architecture and Urban Design

The *Chair of Computer Science in Architecture and Urban Design* performs studies in two kinds of applications of digital media. First, VR is used as a tool for planning real existing architecture and secondly VR itself is used as a place of architecture. Consequently CAD and applications of VR in CAD/CAAD are of high importance for the ongoing studies.

In the research group of the “atelier, virtual” the VR activities of the *Chair of Computer Science in Architecture and Urban Design*, the *Chair of Databanks and Communication Systems* and the *Chair of Graphic Data Processing* are combined. The research topics are related to virtual communication concepts, hardware of VR-platforms, application of VR for CAAD, tactile feedback, surveys on HMD’s, and design of a software framework for VR-applications.

Several further projects deal with determining the amount of subjective presence in Virtual Realities. The studies are based on trials with subsequent questionnaires and subjective ratings. A picture of an example study is shown in Fig. 7C.6.

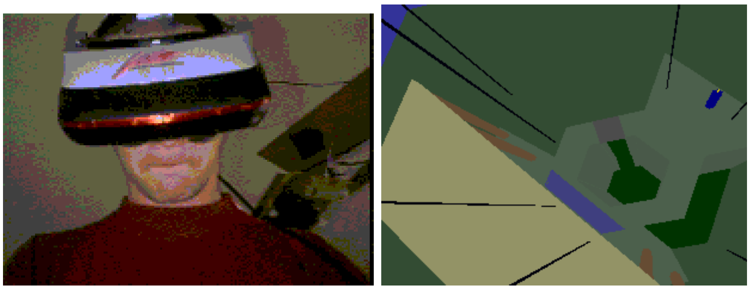

Fig. 7C.6: Acrophobia experiments giving evidence for sense of presence

In this study, which has been performed in cooperation with the *Institute of Psychology* of the *University of Jena*, the effect of VR has been analyzed using the amount of subjective acrophobia (fear of heights) as indicator. It has been concluded that VR can elicit real emotions and evoke a high sense of presence.

- Internet-sites:
  http://www.uni-weimar.de/architektur/InfAR/
  http://www.uni-weimar.de/architektur/InfAR/forschung/vradmin.html
  http://www.uni-jena.de/~sth/angst/acrophobia.htm

7C.3.1.7 Technical university of Clausthal – Institute for Process and Production Management Technology (IPP)

Founded as an institute of the *Faculty of Mechanical and Process Engineering*, the *Institute for Process and Production Management Technology (IPP)* carries out applied research studies in the areas of computer sciences in production processes. The focus is on the introduction of modern computer-based technology for enhancing the quality and efficiency of the production process. In this connection research topics in the areas of software development toolsets, human-computer interfaces, knowledge-based systems, CAD, speech recognition, neuronal networks, multi-media, and Virtual Reality are analyzed.

At the *IPP* multi-media and VR are considered to have high potential to enhance the human-computer interaction in process management. It is realized, that a sensible use of VR in this domain has to take into account technical and ergonomic needs. Therefore prototyping and analysis of VR applications in process management are analyzed with special regards to human-computer interaction.

An ongoing project deals with an application of Artificial Reality in supporting maintenance tasks. In maintenance the personal needs often special information about objects. This lack of information may causes several problems, like forgetting information about the object, non-ready printed information, and misinterpretation of information material. To minimize the problems, a supporting system has been realized using a commercial-of-the-shelf semi-transparent display and a position sensor. This first realization is shown in Fig. 7C.7.

Fig. 7C.7: Augmented Reality to support maintenance tasks

The supporting system consists of a computer, a display, and a position sensor. The display projects information about the focussed item directly into the field-of-view of the operator. The information might be repair instructions, maintenance information or additional information. Further applications of the display are education in maintenance or a portable information system. In this case looking at an object or a machine would be enough to gain information about its function, status, etc. This would make additional food walks and search in papers unnecessary.

- Internet-sites:
  http://www.ipp.tu-clausthal.de/Forschung.html
  http://www.ipp.tu-clausthal.de/forschung/vrp.html
  http://www.ipp.tu-clausthal.de/forschung/car.htm

7C.3.2 GMD – German National Research Center for Information Technology

The *GMD (Gesellschaft für Mathematik und Datensysteme)* performs basic research studies as well as applied studies in the area of computer sciences. It is a non-profit organization, whose shareholders are the Federal Republic of Germany (90%) and the federal states of North Rhine-Westphalia (3,3%), Hessen (3,3%), and Berlin (3,3%).

The main foci of research are system design technology, communication, and cooperation systems, intelligent multimedia systems, and scientific computing. Research studies on topics of Virtual Environments are carried out at the *Institute for Media Communication (IMK).* The overall goal is to expand the scope of new media by research and explore its potential and consequences. Key topics are distributed real-time media, digital story telling, intuitive interface environments, and corporate media network. At the moment 116 employees are working at the *IMK.*

The *Virtual Environment division* of *IMK* consists of 20 scientists. The main goal is to prototype novel applications and services to find out the potential of VE-technology. The *VE division* performs research and development studies in the areas of

- Collaboratively shared Virtual Environments,
- Scientific Visualization,
- Immersive Telepresence,
- Art & Music in VE.

For these studies a high-end infrastructure is available, including graphic workstations, CAVE, Workbenches, and various interaction devices. For software development a VE framework (AVANGO) and a telepresence system (TELEPORT) have been developed and are applicable. A connection to virtual studio techniques and broadband networking brings along further promising capabilities. The main application areas of VE are geoscience, engineering, medical visualization, museums and exhibitions, and telecommunications. Further research is conducted in shared virtual worlds, global illumination, physical simulation, synthetic life, and user interface design. These studies are preformed considering especially computer science issues.

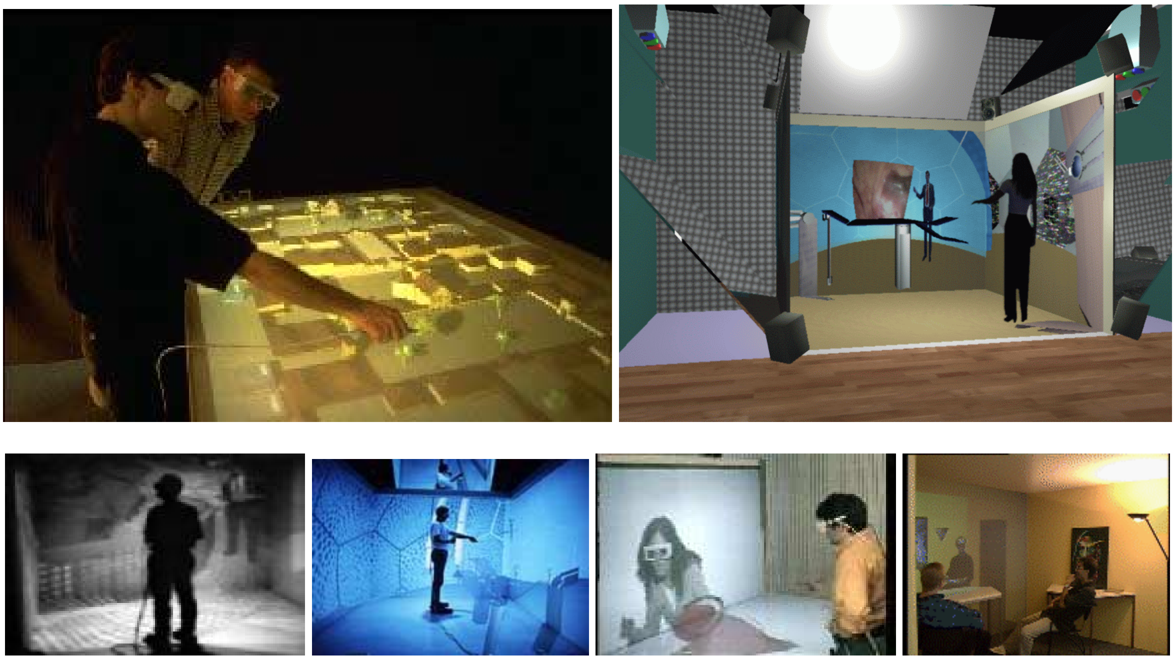

Fig. 7C.8: Responsive Workbench and CAVE at GMD-IMK and further VE-applications (CAVE, Virtual Spaces, CMW, TELEPORT)

Actual projects, as shown in Fig. 7C.8, are based on the Virtual Environment framework AVANGO and immersive displays like CAVE, Responsive Workbench, CyberStage, or Teleport. One goal is the advancement of the VE-framework taking into account distributed environments. In this connection, in the project of collaborative medical workbenches (CMW) collaborative medical working environments using responsive workbenches are analyzed. Responsive workbenches are connected to each other by network forming a new collaborative virtual environment for medical applications.

Other projects are funded by the oil and gas industry and show the impact of VE in this branch. Furthermore, several research projects dealing with presentations, museums, and arts are carried out.

- Internet-sites:
  http://www.gmd.de/IMK/
  http://imk.gmd.de/Virtual_Environments.mhtml
  http://imk.gmd.de/ve

7C.3.3 Max-Planck Institute for Biological Cybernetics

The *Max-Planck-Society*, one of the major independent fundamental research establishments in Germany, supports research studies in separate institutes. The institutes' research activities are focussed on fundamental research in sciences, biology, and humanities. The society is funded 95% by public authorities; 5% is funded by memberships, donations, and industry.

The *Max-Planck Institute for Biological Cybernetics* originally concentrated their efforts on the acquisition and processing of visual information in the nervous system. This has been shifted toward the elucidation of cognitive processes recently.

Fundamental research issues related to VR are analyzed in the *Psychophysics Department*. The main goals are the analysis of visual recognition, spatial cognition, and sensor-motor integration. In the area of spatial cognition two projects are carried out using VR to gain insights into human navigation. The overall goal is to gain information about the capability of humans to navigate through known and unknown environments. In this connection, the information humans store and use for navigation purposes, and how they acquire and access this information has been analyzed. The setup used for this project called HEXATOWN can be seen in Fig. 7C.9.

Fig 7C.9: Experimental environment of HEXATOWN

In these experiments perceptive and cognitive factors are being analyzed. Other projects consider sensor-motor integration with special interest in grasping. However, the activities in this area are not necessary connected to VR, but their results are important for future VR-systems.

- Internet-sites:
  http://www.kyb.tuebingen.mpg.de/index.html
  http://www.kyb.tuebingen.mpg.de/bu/projects/index.html

7C.3.4 Fraunhofer Gesellschaft (FhG)

The *Fraunhofer Society (FhG)* carries out studies of applied research for industry and government. It consists of 50 research institutes with a staff of around 9,000 scientists and engineers. The range of topics is very broad, starting from atmospheric environments and ending at wood research.

VR is a topic in different institutes. The main institutes are: The Institute for Computer Graphics (FhG-IGD), the Institute for Industrial Engineering (FhG-IAO) and the Institute for Manufacturing Engineering and Automation (FhG-IPA).

7C.3.4.1 Fraunhofer Institute for Computer Graphics (FhG-IGD)

The *Fraunhofer Institute for Computer Graphics (FhG-IGD)* is located in Darmstadt and has branches in Rostock, Providence (USA), and Singapore. It was founded in 1987. The research activities are development of product prototypes (Hard- and Software), and realization of concept, models and solutions for computer graphics and its adaptation to specific application requirements. Furthermore basic research projects are carried out. According to IGD-reports, at the moment about 180 employees are working at the IGD and about 350 projects are carried out. Current R&D-projects are dealing with topics of industry, trade, traffic, and service. They include studies, consulting tasks, conceptual development, software development, and software modification.

IGD consists of nine research departments. Their activities are:

- *A1 - Document Imaging*: Digital processing and communication of multimedia documents and their application in the operational and industrial practice.
- *A2 - Industrial Applications*: Realization of the Virtual Engineering concept.
- *A3 – Animation and Image Communication*: 2D/3D multimedia technologies to interactively communicate ideas and products with multimedia.
- *A4 – Visualization and Virtual Reality*: Technology competence and innovative solutions in the area of Scientific Visualization, Virtual Reality, and Augmented Reality.
- *A5 – Graphic Information Systems*: Facility management and spatial information system.
- *A6 – Cooperative Hypermedia Systems*: System design, system architectures, development of components, and consulting in the application areas of multimedia learning, training, simulation and validation, information brokering and interactive tele-services.
- *A7 – Cognitive Computing and Medical Imaging*: Visual Computing, Medical Imaging, and Multimedia Interfaces.
- *A8 – Security Technology for Graphics and Communication Systems*: Realization of security services
- *A9 – Communication and Cooperation*: Multimedia communication and user interfaces for cooperative work in distributed environments as well as agent technology.

Main research issues are the areas of computer sciences and computer graphics. Human factor issues are considered with regards to 3D Interaction and Visualization (Dept. A2 and A4), Augmented Reality (A4 and A7) and Graphical User Interfaces (A2).

The *Virtual Reality department* consists of 22 scientists of computer sciences, mathematics, physics, and mechanical engineering. Among others, important topics handled in this department are scientific visualization of massive amounts of data, human-computer interaction in VR and augmented reality.

For these studies a high-end technical equipment is used. It consist of a 5-sided CAVE (2,4 x 2,4 m base size), as shown in Fig. 7C.10, motion platform, PHANToM device, Spacemouse, Cyberglove, etc. Different graphic workstations, SGI-ONYX (3xIR) and SGI-ONYX (2xIR), are used as graphic rendering platforms.

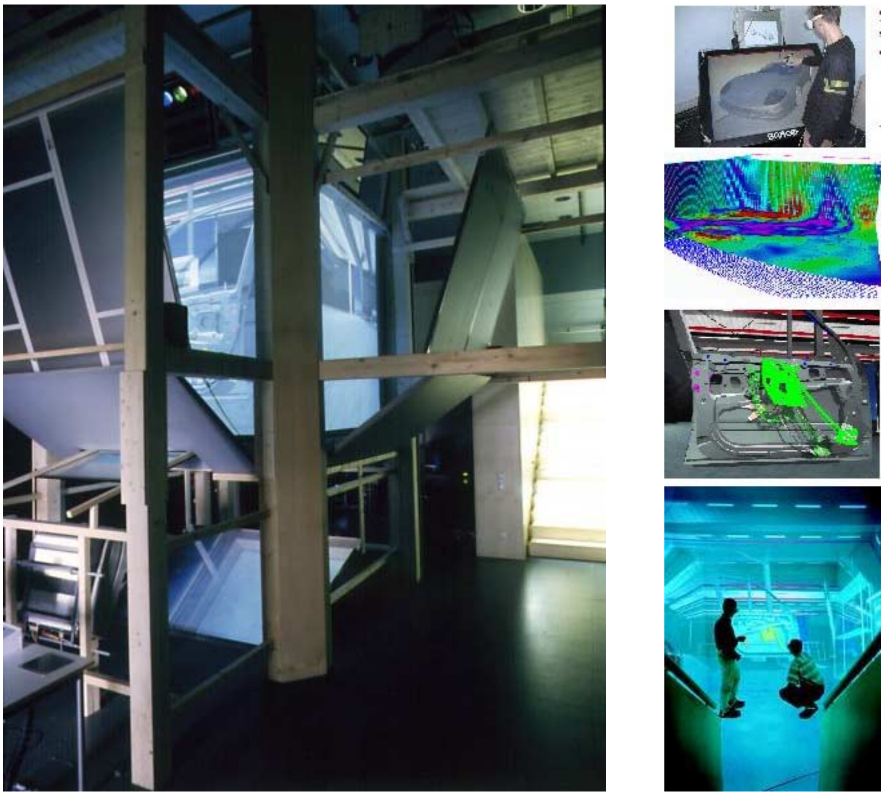

Fig. 7C.10: IGD's 5-side CAVE (left) and sample applications (right)

In the *Industrial Applications department*, workbenches or large stereoscopic projections planes are used as displays to analyze VR interaction in the design process. The overall goal is to make VR-technology applicable to industrial applications. In this connection CAD and 3D-Modelling are other important topics.

- Internet-sites:
  http://www.igd.fhg.de/
  http://www.igd.fhg.de/igd-a4/index.html

7C.3.4.2 Fraunhofer Institute for Industrial Engineering (FhG-IAO)

The *Fraunhofer Institute for Industrial Engineering (FhG-IAO)* is engaged in various areas of technology management. Therefore the institute develops special technology strategies with regard to the market and customers, taking into account properties of human, technology, and organization to guarantee individual and social demands of the human operator. Research and development projects are performed for federal and industrial clients including research programs of the EU (BRITE, RACE, ESPRIT, SPRING) and the Ministry of Education and Research. More than 64% of the institute's funding comes from industrial clients.

The *FhG-IAO* cooperates very closely with the *Institute of Human Factors and Technology Management (IAT)* of the *University of Stuttgart*. Therefore the activities of both institutes are overlapping. At the moment both institutes have more than 240 permanent employees and more than 400 student workers.

Among other topics, the application of VR in the design and production planning process is analyzed. This is done with special regard to issues in the areas of human engineering, software management, technology, and Virtual Reality technology. These topics are handled at the *Competence Center (CC) Virtual Reality*. At the moment the center employs 11 scientists.

At the *CC Virtual Reality* it is considered, that VR expands the possibilities of visualization and interaction with computer-based systems. The user is included in the data space, making it possible to experience a product in an early design process. The overall goal of the activities is to determine new application areas and application-oriented potential of VR-technology. Most projects and studies are related to human factors and ergonomics in design and working processes.

Fig. 7C.11: IAO CC Virtual Reality: Modular Modeling System *M-Modul* (left), CAVE (right)

Projects include a software development system for interactive VR-applications. The system has an open software architecture, which makes application-oriented expansions and modifications of components possible.

Other major topics include HCI-issues, because HCI is an important factor for the acceptance of new computer systems. Virtual prototyping and general use of VR are also analyzed. This includes the first pre-development phase as well as development, production, and reengineering phases of the production cycle. In this connection topics of data visualization and manipulation are analyzed.

Widely connected to this topic is Virtual Modeling. A VR-system is likely to be more suited for intuitive work, real-time-interaction and 1:1 scaling than a conventional desktop computer. For this reason research studies are carried out to create a tool for immersive modeling. Further topics are ergonomic analysis, design, and architecture.

- Internet-sites:
  http://www.iao.fhg.de/
  http://vr.iao.fhg.de/

7C.3.4.3 Fraunhofer Institute for Manufacuring Engineering and Automation (FhG-IPA)

Founded in 1959 in Stuttgart, the *Institute for Manufacturing Engineering and Automation (FhG-IPA)* today employs about 200 scientists. Nearly 60% of the budget is funded by industry. The main topics of the institute are company management, automatization and production technology. VR related topics are handled by the department of technical production planning. The overall goal is the development and design of a virtual / digital factory. A distributed simulation of complex production and material flow system in real time shall be implemented. The results shall be documented and presented using a VR-system. Therefore VR and 3D-realtime simulation are being developed.

Further uses of the VR-system for presentation of industrial, medical, and marketing projects are intended. For this reason VR is used to visualize sensor data and complex 3D-data in an understandable way.

Fig. 7C.12: Future applications of VR at *IPA* (starting left): Rapid prototyping, medical education and micro-surgery

Future possible applications are seen in medical applications, including virtual prototyping of medical workplaces, visualization of anatomic properties for medical education and diagnostics as well as (tele-)operation of micro-surgery robots. They are shown in Fig. 7C.12.

- Internet-sites:
  http://www.ipa.fhg.de/

7C.3.5 Research Establishment for Applied Sciences (FGAN) – Research Institute for Communication, Information Processing, and Ergonomics (FKIE)

FGAN (Research Establishment for Applied Sciences) conducts scientific research for the German Ministry of Defense. The main activities are research and development of defense techniques, especially to improve the efficiency of actual and future reconnaissance, and command & control systems. Additionally *FGAN* has the scope of providing scientific/technical expertise for the German Ministry of Defense and to participate in national and international co-operations.

The *Research Institute for Communication, Information Processing, and Ergonomics (FKIE)* conducts research in the area of design improvement of military information systems as part of Command & Control (C^2) and reconnaissance. The *Ergonomics and Information Systems (EFS) department* of FKIE focuses on ergonomic issues in this area.

In the research project *Electronic Sandtable (ELSA)* the application of VR in C^2 is analyzed. It is intended to build an experimental prototype for three-dimensional visualization of geographic and tactical information, allowing intensive interaction with the data. This is done with special regard to issues in the areas of human factors and human-computer interaction. Especially the areas of stereoscopic visualization on large displays, and navigation, manipulation, and cooperation in shared VR have been identified to be of critical importance.

Fig. 7C.13: The Electronic Sandtable (ELSA) at FGAN/FKIE

As testbed a Virtual Workbench has been built shown in Fig. 7C.13, and a software framework has been developed. First experiments considering visualization will start in 2000.

Other VR-applications include a walk-through visualization of the Combat Information Center (CIC) of future vessels. This was implemented using a wall-size stereoscopic projection facility.

The VR infrastructure consists of one SGI Onyx2 IR2 as primary graphics workstation, which is supported by several smaller SGI workstations. As displays a wall-size stereoscopic projection facility and two workbenches are present. The software used is widely commercial of the shelf which is expanded by own software developments.

- Internet-sites:
  http://www.fgan.de/
  http://www.fgan.de/fgan_info/fkie/fkie_efs.htm

7C.4 Commercial Users & Industry

Commercial and industrial applications of VR are in an early phase, as mentioned before. The most common application is presentation of design studies for future products. Nevertheless further applications in the areas of rapid prototyping and rapid engineering are starting.

Another area is the distribution and development of VR-systems itself. This includes software developing companies as well as hardware developers and distributors. Other companies are working in the area of consulting and seeking out possible applications of VR in design and production processes.

In this chapter the main commercial VR-developers and industrial users are described.

7C.4.1 TAN Projection Technology

TAN Projection Technology is specialized on high-end graphic projection systems, especially for three-dimensional stereoscopic visualization.

The company’s main products are the TAN CUBE, which is a 4-, 5- or 6-side projection system like a CAVE, the TAN HoloBench, which is an L-shape dual plane 3D table, the Responsive Workbench, a single-sided 3D table, and TAN Stereovision as high-end stereoscopic wall projection system.

The company understands itself as a system integrator, this means it offers optimization of the complete display. The optimization also includes modifications to the projection systems available (out-of-axis projection, convergence stability) and development of peripheral technologies.

The major partners of TAN are SGI, Cenit, vrcom, and vircinity. For the development TAN has strong connections to academic partners like the FhG-IGD and the GMD. The references of clients are

- *4 Sided CUBE*: Fraunhofer Institute IAO Stuttgart, Fraunhofer Institute IGD Darmstadt, GMD Sankt Augustin, Volkswagen AG, Daimler-Chrysler AG, Super Computing Center University Stuttgart, BMW AG, Adam Opel/General Motors AG, Brown University Providence/USA,
- *5 Sided CUBE*: Fraunhofer Institute IGD Darmstadt, Chalmers University in Gothenborg/Sweden,
- *6 Sided CUBE*: Royal Institute PDC/KTH in Stockholm/Sweden, Aalborg University Denmark.

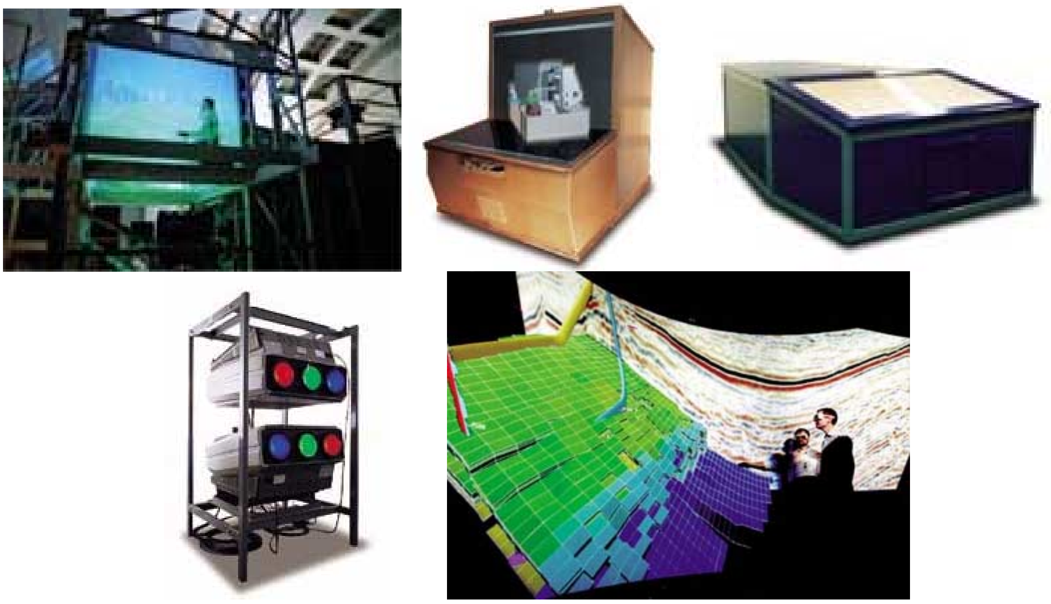

Fig. 7C.14: TAN projection systems: CUBE, HoloBench, Responsive Workbench, Stereovision, TANORAMA

Ongoing projects are carried out for further customers, including EDAG-Germany, UNI-C Lyngby, Denmark, PGS-Houston, USA, PGS-London, UK, AUDI AG, FhG-IFF, Magdeburg, INRIA-Research Institut, Paris-France, Statoil- Norway.

- Internet-sites:
  http://www.tan.de/

7C.4.2 Art+Com Medientechnologie & Gestaltung GmbH

The main goal of *Art+Com* is to use innovative graphic computers for visualization and design. The company carries out projects with a multidisciplinary approach, involving a team of scientists, architects, technicians, and artists. Presentations have been used at various exhibitions including Siggraph and Imagina. These presentations and layouts using VE-technology is one main domain of *art+com*.

Further projects are carried out for the industry with special regard to interactive multi-media tasks and distributed virtual systems. Industrial clients are DaimlerChrysler, Deutsche Telekom, and Siemens AG. An example of using VE in design of a Mercedes car interior is shown in Fig. 7C.15.

Other scopes of business are town building and architecture, television, multi-media, and interactive network services.

Fig. 7C.15: Design of a Mercedes Benz car interior using VE

- Internet-sites:
  http://www.artcom.de/

7C.4.3 Echtzeit AG

The Echtzeit AG offers services in the area of Virtual Reality and Infoware. The overall goal is the visual simulation of information, navigation, and communication processes to facilitate a fast and easy understandable handling of business processes. In this area the company offers production, image editing and animation software as well as databank solutions. Projects in the area of VR are dealing with visualization of architecture, urban simulation, real time visualization tools, VR-showcases, and multi-media environments.

Important clients of Echtzeit AG are Deutsche Telekom, IBM Germany, German Television, diverse museums, SGI, Multigen-Paradigm Inc., several banks, etc.

- Internet-sites:
  http://www.echtzeit.de/

7C.4.4 Event Consulting GmbH

Event Consulting is working in the area of company consulting with special regards to VR and Internet technologies.

According to own statements, the main goals are: Analysis and adaptation of existing VR-processes, development of concepts and strategies for VR-implementation, selection, coordination, and support of possible cooperation partners, definition of new VR-applications, identification of new areas for VR (especially marketing and distribution) and support of VR-projects.

- Internet-sites:
  http://www.event-consulting.de/

7C.4.5 Daimler-Chrysler

Daimler-Chrysler Corporation performs many activities in the area of VR. The company structure itself is very complex and includes branches of automotive, civil and military aerospace, services, and information systems. For this reason various branches are working in different application fields of VR.

The key branch for Virtual Reality is the *Virtual Reality Competence Center (VRCC)* of the *Daimler-Chrysler Research Center* in Ulm, Germany. The *VRCC* supports activities and studies in the VR area by providing other departments of Daimler-Chrysler with technical infrastructure and personal support.

The technical infrastructure consists of high-end graphic computers and diverse displays like a 4-channel CAVE, HMD, BOOM, multi pipe projection, and multi view displays. For interaction several I/O-devices and motion trackers (electromagnetic, optic, and ultrasonic) are present.

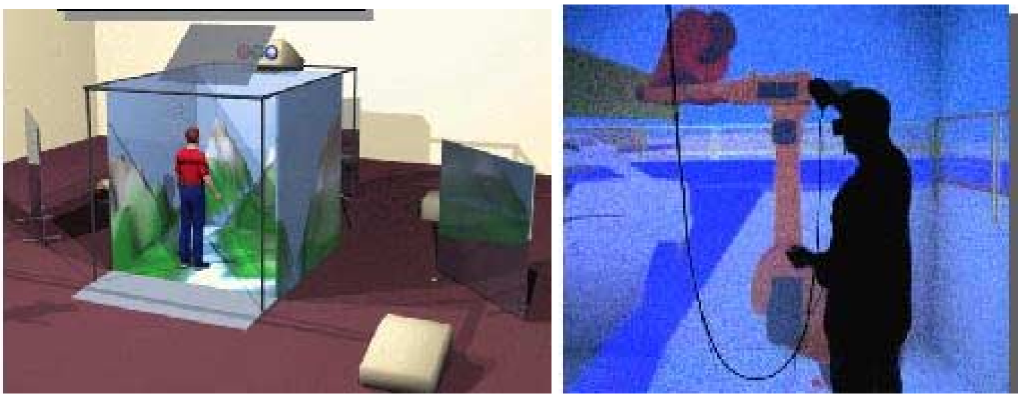

Fig. 7C.16: The CAVE at *Daimler-Chrysler's VRCC*

VRCC's main goal of using VR-technology is first to construct a high quality visualization for styling, e.g. to generate a virtual showroom of products. In this showroom the products (cars, busses, airplanes, trams) can be presented to a potential customer in a realistic way and a natural environment. Another topic is virtual manufacturing. This includes the use of VR in the production process to visualization working tasks or to program robots offline in a virtual workcell. Virtual prototyping is a further topic, as it has been used to design a defensive system and for ergonomic investigation of the interior of cars. Moreover, simulation data, which is data representing the physical behavior of objects like driving dynamic data, can be visualized. Future applications of VR are seen in battlefield simulation, mixed mockups, Augmented Reality and distributed VR.

The stinger antiaircraft weapon of *DASA Dornier* is one of the first VR-systems which has been introduced to the German army. A picture of the system is shown in Fig. 7C.17. This system simulates the scenario, weapon, visor, teampartner (figurine), and use of binoculars by the teamleader. The system has been found very advantageous because of changeable scenars, easy installation, high integration mobility, and possibilities for supervision by monitor.

Fig. 7C.17: Training of the Stinger antiaircraft weapon in VR

Another branch using VR is the aerospace division of Daimler-Chrysler: the *DASA*. For aircabin design an industrial design process using VR models and "Walk through" is planed in future. Therefore the use of 3D-CAD is enhanced. The division on military aircrafts (*DASA Military Aircraft, Munich*) is working in the area of virtual process management and the establishment of a Virtual Simulator. The Virtual Simulator is a flexible extension to VR. The pilot is seated in a generic cockpit, which can be easily adjusted to different layouts. Pilot sight is simulated by means of VR, while haptic feedback is given by real hardware.

- Internet-sites:
  http://www.daimlerchrysler.de/
  http://www.debis.de/debis/systemhaus/branchenzentren/fertigungsindustrie/News_Events/events/Virtuelle%20Produktentwicklung/
  http://www.dasa.de/dasa/g/defence/army/educat/aus05.htm
  http://www.dasa.de/dasa/g/milair/fcs/sim_04.htm

7C.4.6 Automotive Industry

Other automotive companies are starting to use VR. In Germany the companies of Opel, Ford, and Volkswagen are on their way to establish own VR centers or have already done this. Unfortunately no information was available on the status of their work making it impossible to include the activities in this report.

7C.5 Résumé

This report has given an overview above the activities on Virtual Reality and Virtual Environments in Germany. It has been shown that VR is still a research topic. Research studies are performed at a lot of academic establishments, including universities and independent research institutes.

As VR is also a very cost- an personal-intensive topic, many institutions have established Competence Centers of Virtual Reality supporting other departments and clients with technological and personal infrastructure. This trend can be observed especially at the high-end computer centers at universities and at research departments of major companies.

Today, VR itself is still a broad research topic including questions in the areas of computer science and ergonomics, so that a lot of institutions are carrying out research studies in this area.

Apart from VR as research topic itself, VR is used frequently for presentation of future products and visualization of massive amounts of complex data. For these application the system might not work taking advance of all possible benefits, but the existing benefits are enough to favor it instead of other display technologies.

The use of VR as a training tool is often mentioned, but a close look on the concrete projects shows that there are still many open questions. Apart from one single use, the application of training is still a future vision. The same is true for virtual prototyping and virtual engineering.

However, especially the rising activities in research, development, and application of VR shows that the potential of VR is generally considered to be high. The number of establishments of VR centers, which offer the generation and use of a high-end VR-system to a customer, shows, that a huge demand on VR exists on the market. Again, this shows the growing importance of Virtual Reality and Virtual Environments in future.

7D - Simulation Systems/Methods (VR) used in the Norwegian Armed Forces

7D.1 Army

7D.1.1 Simulation & Training Centre, Armour School/Norwegian Cavalry, Rena leir

The objective of the Training Centre is to educate officers and conscripts for service on armoured vehicles in the Norwegian Army, as drivers, gunners, or vehicle commanders.

7D.1.1.1 Computer Based Training (CBT)

This is an interactive program with advanced multimedia-technology (text, voice, videos, pictures, animations, and drawings) used to teach students basic knowledge about the tanks Leopard 1 A5 MBT and CV9030 IFV. CBT consists of a classroom with 12 student PCs and one instructor PC which are connected in a network. Each PC has a headphone for the sound. The student can adjust the progress of the education to his own pace. Each lesson ends with a test, and the results are stored on a database for evaluation by the instructors. The results from an investigation carried out at the Training Centre show that the performances following CBT are markedly improved compared to those obtained by conventional lectures. The equipment is delivered by Thomson Training & Simulation, England.

7D.1.1.2 Combined Combat Simulator (CCS)

This system allows training of gunners on the tanks MBT and IFV as well as teams, platoons, and companies. The combat simulator yields: realistic training, better quality and higher level of training, development of combat techniques and tactics, improved combat capability, reduced cost of materiel and equipment during basic education. CCS consists of 4 cabins of Leopard 1 A5 with 2 instructor stations, 4 cabins of CV 9030 IFV with 2 instructor stations, 2 auditoriums for preplanning and evaluation, open hatch observation on 180 degrees wide screen, closed hatch observation on 360 degrees sights and periscopes. The equipment has been delivered by Kongsberg Defence & Aerospace, Norway.

7D.1.1.3 Driver Trainer Simulator (DTS)

Mock-up simulators provide basic and advanced training of drivers on Leopard MBT and CV 9030 IFV tanks. DTS can be used to train normal driving techniques in a variety of terrain day or night. It can also be used to train emergency techniques in varying terrain day and night. The system reduces the cost of using real equipment during basic training. DTS consists of computer generated terrain from areas in North and South Norway (about 12 square kilometres), 2 moving Leopard MBT simulators, 2 moving CV 9030 IFV simulators, and 4 instructor stations. Each simulator can be observed by 4 other students, who can look at a 180 degrees wide screen and see the same landscape as the student driver and the instrument panel of the vehicle. The equipment has been delivered by Atlas, Germany.

7D.1.1.4 Gunnery Simulator System

This system has been made as a simulator device for MBT and IFV gunners, teams, platoons, and companies. The gunnery trainer is used for in door and out door laser based range. Combat exercise can be trained against other tanks or units for tactical skills. Immediate feedback is given to the crews, and data are stored on a disc for later evaluation by the instructors. The system is also used for

selection of gunners and loaders on Leopard. The BT 46 Basic Training laser based gunnery simulator for Leopard 1 A5 is delivered by SAAB Training Systems, Sweden.

7D.1.1.5 Army Training Simulator

This is a simulator made for small arms and AT weapons used for basic training of all soldiers. It is also used for advanced training and techniques for recognising squads and infantry squads. The system consists of in door firing range with sensor technology in which 4 – 6 soldiers can train simultaneously. The distance between weapon and screen is 7 metres. Target and scenario can be changed by the instructor. Types of weapons used are: AG 3, MP 5, 84 millimetres Carl Gustaf Recoilless Gun, and M-72 Rocket Launcher. The equipment has been delivered by FATS Inc, USA.

7D.1.2 Tactical Training Centre of the Army, Rena leir

The activity of this centre is based on simulator systems for teaching and training units, officers, and conscripts in the Army. Modern technology has been taken into use to simulate combat scenarios in a credible manner. During exercises, relevant data are collected, and immediate feedback based on the performances is given. The system allows rehearsals and specific training of details. Training at the centre will be cost effective, because the need to perform real exercises in the nature will be reduced.

7D.2 Navy

7D.2.1 Tactical Air Defence Weapon Trainer (LUSI), Haakonsvern, Bergen

LUSI is made for training of gunners and gun commanders on naval vessels. A mock-up platform consists of 2 guns on a movable deck. The platform is placed in a dome-like room with a 270 x 90 degrees wide screen of a real coastal landscape. Laser based tracking light aids the gunner in hitting the targets, which are aeroplanes of various types. Sounds from the aeroplanes and the gun in use make the scenario rather realistic. Various categories of personnel can be trained with the programs of LUSI. More specifically, training can be made on reaction time, stress, and decision making. The skills of the gunners can be monitored and evaluated. The system can also be used for selection purposes. A number of types of weapon can be applied (e.g. Mistral Simbad and Manpad). The equipment has been delivered by Kongsberg Defence & Aerospace, Norway.

7D.2.2 Royal Norwegian Navy Submarine School Simulators, Haakonsvern, Bergen

The Submarine School is the educational unit of Comtrainsubs. The school provides a wide range of courses in safety, technical, and tactical subjects for all submarine crewmembers from the level of inexperienced sailor to Submarine Captain or Chief Engineer. In addition to these courses, the school supports submarine crews during work-up and provides evaluation personnel for musters. These activities combine the teaching of theory and the use of simulators.

There are 4 full-mission simulators at the Submarine School. I) The Kobben Tactical Simulator allows for training in the use of torpedoes, the MSI-70U weapon control system, the Kobben-class Integrated Command Control and Information system, periscope, plotting table and sonar. II) The Ula Tactical Simulator facilitates training for most types of tactical submarine operations. This includes operation of torpedoes, the MSI-90U weapon control system, plotting table, periscope, and sonar. Communication via the intercom system, VHF, and underwater telephone contribute to increase the experience of realism. III) The Ula Steering Control Console Simulator with motion platform provides realistic training for the roles of helmsman and officer of the watch on all operating depths with a wide range of sea states and trimming of ship. This simulator can be linked to the Ula Engineering Simulator for larger scenario exercises. IV) The Ula Engineering Simulator provides training in the operation of the Engineering Control Console, the main electrical switchboard, water station, various valves operated when preparing for or securing from snorkelling and valves connected to other equipment. Smoke generators are also fitted for realistic fire drills. All simulators

can be used for a wide range of skills, varying from training a single operator to full scale scenarios for all crewmembers.

7D.2.3 Royal Norwegian Navigation Centre, Naval Academy, Bergen

The centre has 2 simulators of full-scale bridge. The simulators can be configured to fit the bridges of all naval vessels in use in the Navy and also civilian vessels. Selected areas of Norway and some European countries are made ready for navigation. A number of elements can be inserted into the scenarios, like aeroplanes, vessels, oil platforms, and lifeboats (fleets). The simulators have been delivered by Atlas, Germany. The Navigation Centre makes up the professional council of the Inspector General (Marshal) in matters of navigation. The objective of the centre is to maintain the highest level of skills in exerting bridge navigation on naval vessels and to be in the front of the development within the field of navigation. The centre has been divided into 3 departments. I) Department of Education is responsible for all certificate based education within navigation at the Academy. The department also takes part in teaching students in the simulators. II) Department of Projects advises regarding navigation instruments, technical solutions, and other matters in the field of navigation. The department represents the Navy in numerous military and civilian forums. III) Department of Training is responsible for all practical navigation at the Academy. A staff of instructors is involved in administration and training of personnel. The department also controls the standard of navigation on board all naval vessels at regular intervals.

7D.3 Air Force

7D.3.1 F-16 flight simulators are located at the Air Force bases Rygge and Bodø

The simulator consists of a mock-up of a cockpit standing in front of a screen. An up-dated version has been made to follow the renewal program of the aircraft. All simulators have been delivered by Lockheed Martin.

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7E - Spain

7E.1 Simulador de Grupo de Artillería de Campaña (SIMACA)

The purpose of the Artillery Simulator is to provide co-ordinated training to all members of a field artillery group. The complete configuration of the simulator includes forward observer positions, fire direction centres, battery guns, an instruction station, an administrator station and operations room for briefing/ debriefing. A SIMACA prototype has been installed in the Artillery Academy in Segovia. The training simulator has been designed based on the following characteristics:

- Suitability and high fidelity of the generated visual and acoustic environment for the Forward Observer
- Suitability and fidelity in the simulation of the regulatory equipment used by the Forward Observer (binoculars, compass, goniometer and GPS).
- The high fidelity in the ballistic simulation (integrated artillery weapons).
- Addition of FDCs rooms to be occupied by artillery people performing the calculus functions as an alternative way, more realistic, to the synthetic simulation of FDCs.
- Friendly, unfriendly troops movements (pseudo-intelligent logic as to avoid obstacles or to react to enemy´s fire and vulnerability models).
- The capability of the simulator to interact with other simulation devices, increasing the complexity and the realism of the training for the Forward Observers just as the training of the other simulator's users.

- VE/VR Technologies versus Simulator Technical Characteristics

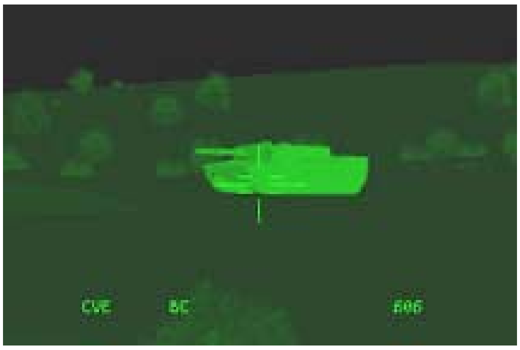
VE/VR Technologies	Technical Characteristics
Visual System	• Onyx2 Infinity Reality, 10R10000, 3 graphics pipeline. • Spherical screen (125ºH x 33.75ºV). • VR binocular vision. • Integrated goniometer (VR tubes with LCD base).
Navigation System	• Pholemus Fastrack (binoculars and compass), and other position sensors (artillery weapons).
Auditory System	• Stereo sound AudioWork
Interoperability	• High Level Architecture (HLA).

- Human factors analysis is not yet reported.
- Internet-site:
  http://www.grupotecnobit.com

7E.2 Entrenador Universal de Misiles Portátiles (EUMP)

The “Entrenador Universal de Misiles Portátiles (EUMP)” is an A/T and A/A missile launcher simulation system intended for gunner training. An EUMP prototype has been installed in the Infantry Academy in Toledo. The trainer has been designed to perform the following functions:

- Tactical situation graphic presentation in which the marksman may accomplish his decision-making.
- Tactical scenario and selected training terrain topography display.
- Marksmanship and target monitoring, shooting, missile guidance, impacts and effects on target or failure.
- Opposing forces movement and action. Targets are the opposing force individual components. They are part of motorized, mechanized or tank small units (squads, sections, and platoons). Opposing forces behavior is in accordance with tactical manual regulations, including their combat capacity against training gunner and protection measures among them.



- VE/VR Technologies versus Simulator Technical Characteristics

VE/VR Technologies	Technical Characteristics
Visual System	• Onyx2 Infinity Reality, 4 R10000, 1 graphics pipeline. • Plane wall screen. • LCD VGA visor gunner with Thermal vision.
Navigation System	• Pholemus Fastrack, and other position sensors.
Auditory System	• Stereo sound AudioWork
Interoperability	• High Level Architecture (HLA).

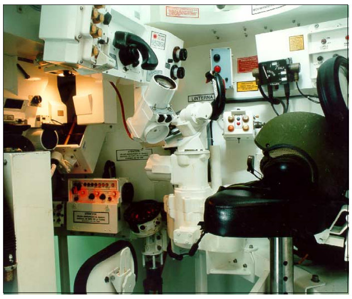
- Human factors analysis is not yet reported.
- Internet-site:
  http://www.espelsa.es

7E.3 M60 A3 TTS Tank Gunnery and Tactical Simulator (M-60)

The M60 A3 TTS tank gunnery and tactical simulator is a Full Mission Tank Simulator with the possibility to operate in virtual scenarios like real military ranges and also to other non geospecific typical operational scenarios. The simulator is now operational and used to train all the M60 tank crews.

The simulator consists of four identical units, each one mounted within a shelter capable to operate individually or together interconnected in platoon mode and operating in a same virtual war scenario. A fifth shelter unit, also interconnected to the four simulators, is dedicated to the follow on, reproduction and debriefing of exercises. Its capacity is up to four complete crew including each one the commander, the driver, the gunner and the loader.

The interconnection is a standard DIS interactive data bus that allows for a wide range of tactical and combined exercises at different levels of complexity. Within the simulated war scenarios many different combinations of friend and/or enemy units and targets, with or without offensive capability, may be present. The simulation is able to provide a wide range and combinations of normal and abnormal operative conditions such as internal tank failures caused or not by the enemy attack.



- VE/VR Technologies versus Simulator Technical Characteristics

VE/VR Technologies	Technical Characteristics
Visual System	• Evans & Sutherland ESIG 4520. • 1024x768 pixels resolution for full screen images. • CRT 14" monitors for normal screens and periscope vision. • CRT 2" for periscope and telescope vision.
Navigation System	• Specially designed Cockpit system.
Auditory System	• Stereo sound system.
Interoperability	• Distributed Interactive Simulation (DIS)

- Human factors analysis is not yet reported.
- Internet-site:
  http://www.sener.es

7E.4 AV8B Harrier II Plus Mission Simulator

The AV8B Harrier II Plus is an interactive dual cockpit Full Mission Simulator capable to train two pilots together in joint air-to-air and air-to-ground missions in synthetic scenarios with high level of realism. Air to air refuelling and carrier operations can be trained as well.

Training is supported both in day and night conditions with Night Vision Goggles. Digital Radar Landmass Simulation (DRLMS) and FLIR and weapons video (IR and laser) simulation is also included. G-cueing simulation covering reaction forces on flight controls (e.g. stick and pedals), g-suit, g-seat and buffet increases the level of immersion in the synthetic environment. Finally, quadraphonic aural cueing provides ambient sounds, emergency tones and communications and moves realism one step further. State of the art computing technology such us fibber optic data links and Power PC boards in the host computer has been used in the development of this simulator.

This top level simulator uses real avionics, two real AV8B cockpits, high fidelity synthetic environment and electronic warfare simulation and high performance visual system with two 24 feet domes and head trackers. Visual projection covers the full field of view of pilots on the real aircraft. The visual scene is computed and displayed at 60 Hz. Each dome contains four target projectors used for close air combat and air-to-ground missions.


- VE/VR Technologies versus Simulator Technical Characteristics

VE/VR Technologies	Technical Characteristics
Visual System	• VistaView Evans&Sutherland ESIG 3000 • Two 24 feet dome projection • One IG for OTW per dome • +140º H x +90º/-40º V Field of Regard • One IG for FLIR and Weapons Video per dome • Four target projector per dome
Navigation System	• One Head tracker per dome
Auditory System	• Quad audio system
Interoperability	• Ad-hoc protocol via fibber optic link at 60 Hz

Reset Centre (dedicated to human factor research related to safety driving devices) is one these users and the Automotive Laboratory of the Polytechnic University of Valencia is other user of the system for its works in the evaluation of driving devices for disabled people.

Apart from this specific application of real-time graphics and simulation the group has extended its fields of research to more applications of these technologies and has a wide experience in the transference of technology with the industry.

- Internet-site:
  http://www.glup.irobot.uv.es

The ARTEC group has collaborated in several European projects in the 4th European Framework:

- **ARTIST- Animation Package for Real Time Simulation. E-20102**. Oriented towards the Research and Development of Basic tools for the simulation in low-cost platforms.

- **CATS - Computer Aided Theatrical Score. E-20340**. Oriented towards the development of a graphic tool that allow to the theatrical director the virtual design and analysis of Theatrical representations.

- **GEOINDEX- Geographical Index System. E-25029**. Project which had as objective the development of and interactive system for the access to geographical data using 3D graphics techniques in low-cost platforms.

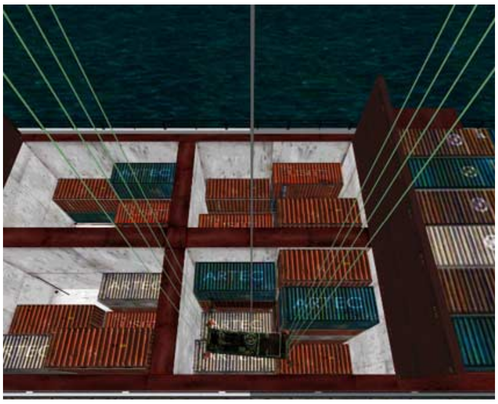
At Spanish and regional Levels the ARTEC group has also a large experience in the development of R+D projects:

- **PIRAMYS**: Integrated Platform for the Representation, Analysis and Modelling of real-time environments. Where basic tools for real-time 3D objects modelling and representation were developed.

- **PRIME**: Interactive Presentation of Ceramic Tiles using virtual environments. This project was oriented to develop an assistance system for the selling of ceramic tiles using immersive environments. This system is currently in use and evaluation in more than 30 sales point of the TAUGRES Company and its planned its extension to the whole sales network.

- **VIRME**: Interactive Visualisation of Railway Material. This project was developed with the company ALSTHOM and was oriented towards the development of basic tools for virtual mock-ups in the field of railway industry.

- **SIVEI**: Training System in Industrial Manufacturing Process using virtual reality Techniques.



Technical Characteristics
• Helmet Mounted Display. • Data Globes. • Stereo sound system.

- **SIVAS:** An Instructional Aid System for Driving Schools Based on Virtual Simulation. This project was oriented to the development of instructional tools using virtual reality technologies.

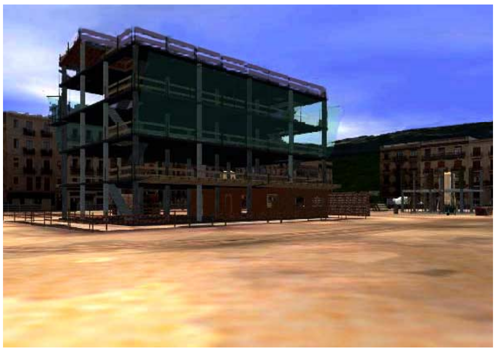
Technical Characteristics
• Planar Projection with high resolution systems. • Motion Platforms with 6 DOF. • Stereo sound system.

- **SIMPRIC:** A training system for Crane and material Transport System operation in Building Areas.

Technical Characteristics

- Planar Projection with high resolution system.
- 6 DOF Joystick.
- 3D Mouse.
- Specially designed Cockpit System.
- Stereo sound system.

- **EVR:** Dangerous Virtual Building. This project was oriented to the development of a virtual building simulator for the training in safety procedures of the building workers.



Technical Characteristics

- High End Cylindrical Projection.
- 6 DOF Joystick.
- 3D Mouse.
- Stereo sound system.

- **SEVALPORT:** Gantry Crane Simulator for Harbour Areas. This project is currently under development. Inside the project a Gantry Crane simulator is being developed including the use of high field of view projections and a motion system platform. The system will be used for the training and re-education of crane operators.

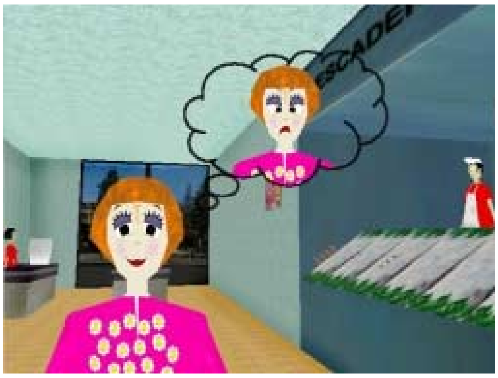
Technical Characteristics

- Planar Projection with high resolution system.
- Specially designed Cockpit System.
- Motion Platform with 6 DOF.
- Stereo sound system.

- **FINESTRET:** Semi-autonomous virtual puppet oriented to the presentation of exhibitions and public acts. Interacts with the publics and is controlled by the voice and gestures are controlled by a human actor.

Technical Characteristics
• Planar Projection with high resolution systems. • Stereoscopy Vision. • Voice Control. • Stereo sound system.

- **IMMER II:** Highly Immersive Environment for the treatment of person with mental diseases and autism.



Technical Characteristics
• Helmet Mounted Display. • Data Globes. • 6 DOF Joystick. • 3D Mouse. • Stereo sound system.

- **High Immersive Visual Simulation Center (VISIONAC):** High End General purpose visualisation facility based on a 6 meters diameters cylindrical screen and a 3 pipes high end graphics workstation, with a 160º of field of view. This facility is open for collaboration in different kinds of projects that needs for high quality immersive visualisation. The system includes stereoscopic projection and three-dimensional sound system.

Technical Characteristics
• High End Cylindrical Projection. • 6 DOF Joystick. • 3D Mouse. • 3D sound system based on a six speakers system.

- **AS350B2 Helicopter Simulator**. This project is developed in collaboration with ESPELSA. In the project a simulator for the training of the helicopter pilots of the Spanish Traffic Administration has been developed. ARTEC has worked mainly in the Visualisation and control systems.

- **VIRTUAL RAMON Y CAJAL MUSEUM**: Educational applications that allows the user to navigate in a virtual lab of D. Santiago Ramon y Cajal and interact with the material and objects used in his research.

7F - VR/VE COMPENDIUM

Human Factors Issues in the Use of Virtual Reality for Military Purposes

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7F1 - Air Force Research Lab – Mesa, AZ

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7F1.1 Current Research Projects

1. Distributed Mission Training Technology Engineering Development;
2. Night Vision Device Aircrew Training Research and Development;
3. Uninhabited Aerial Vehicle Behavioral Research and Training System Development.

7F1.2 Results Achieved To Date

7F1.2.1 Distributed Mission Training (DMT) is a shared training environment comprised of live, virtual, and constructive simulations allowing warfighters to train individually or collectively at all levels of war. DMT allows multiple players at multiple sites to engage in individual and team participation to full theater-level battles. It allows participation, using almost any type of networkable training device, from each weapon system and mission area. Additionally, computer-generated, or constructive, forces can be used to substantially enhance the scenario. This combination of live, virtual, and constructive environments allows nearly unlimited training opportunities for joint and combined forces from their own location or a deployed training site. This expanded capability provides on-demand, realistic training opportunities for all warfighters unconstrained by the fiscal, geopolitical, legal, and scheduling problems associated with current real-world ranges and training exercises that limit training effectiveness and arbitrarily cap readiness levels today. DMT dramatically improves the quality and quantity of warfighter training.

Low-cost, high fidelity, unit-level simulators with full visual systems immerse the warfighter in the “synthetic battlespace” training arena, enabling training throughout the full spectrum of operations. Available at the unit level networked locally and long-haul to other mission level nodes, units will be able to team with other air, ground, sea, and space forces to execute the Air Tasking Order (ATO) in various training scenarios. At other times, units will conduct local training or prepare for major exercises using the DMT system. DMT will also enhance brief, debrief, data collection, and mission replay and analysis to enable effective mission planning and targeting. Furthermore, it will provide combat assessment and improve future combat mission execution thereby dramatically increasing the probability of first mission success.

7F1.2.2 Night Vision Training System (NVTS) in which a complete simulation approach has been adopted. The goal of the NVTS program is to produce high fidelity, deployable, low-cost, NVG simulation that will enable mission training, preview, and rehearsal whenever and wherever necessary.

NVTS is a research and development effort that will continue development and transition to users. The NVG imagery is based upon the modeling of the unique two-dimensional NVG effects such as halos, gain response based on an accurate characterization of goggle sensitivity, gain, resolution, color, and field of view. The imagery is presented through a head tracked CRT-based display mounted in an actual NVG shell. This approach allows for the correct eye-point for all crewmembers. Each display requires at least one channel of imagery. The three-dimensional world incorporates high-resolution material-classified imagery, and accurate per-texel radiometric response of surface reflectance and aspect. The current approach results in a single database which will support completely correlated visible and multiple sensor simulation. Features of the Current NVTS:

- Correlated photographic and material-classified database covers 380 nautical miles by 420 nautical miles of the Nellis training range. This database was derived from multi-spectral satellite imagery, aerial photography, material spectral response data, and DTED elevation data. The database includes insets with sub-meter resolution imagery and full three-dimensional cultural feature extraction;
- The NVG sensor simulation uses a physics-based approach to provide an accurate in-band, radiometric response for reflectance and aspect of the material-coded texel under illumination. As the illumination level and angle change in the simulation, the amount of light reflected from each texel to the viewpoint changes in real time;
- Combat effects have recently been modeled and include several types of explosions, wood and oil burning smoke, missile trails, flares and tracers. All of these effects include near- and in-view effects for haloing, gain, noise, and appearance;
- High-resolution helmet-mounted displays present the simulation to the user. These displays incorporate miniature cathode ray tubes (CRTs) mounted inside NVG shells to provide the same form, fit, and function of actual NVGs, with the same weight and center of gravity as the NVGs being modeled. The CRTs use the same phosphor as current NVGs in order to provide the same color and decay characteristics. Current HMDs have a display resolution up to 1700 pixels by 350 lines, non-interlaced, refreshed at 60Hz.

Future Developments:

- Dynamic shadowing
- Multiple illumination sources
- Weather and atmospherics
- Seasonal variations
- Water effects
- Increased gaming area
- Transition to other platforms
- Training evaluations

7F1.2.3 The role of **Uninhabited Air Vehicles (UAVs)** in Air Force operations is expanding. This expansion is accompanied by an increased emphasis on training UAV operators. As new concepts in UAV control and operator interface are developed, there will inevitably be new challenges in operator training. AFRL/HEA is conducting both basic and applied behavioral research that will inform future Air Force choices regarding the development of a UAV operator training pipeline and the impact of new training technology on operational readiness. We are also designing and building new prototype UAV training systems. These systems will not only help train Predator UAV crews, but will also give us added insight into the future of UAV training. Currently there are three major AFRL/HEA UAV projects. The UCAV Training Research Testbed Project is a basic research project examining various facets of UAV/UCAV operation. The Predator Air Vehicle Operator Flying Experience Study is a large behavioral research study addressing the relevance of manned-cockpit flying experience to UAV Air Vehicle Operator training. The Predator Multi-Task Trainer is a low-cost simulation system that AFRL/HEA is developing for training Predator Air Vehicle Operators and Payload Operators. The goals of the UCAV Training Research Testbed are threefold: (1) to provide a medium-fidelity simulation environment to be

used by Air Force laboratories and universities for basic behavioral research on UAV/UCAV operation; (2) to design synthetic research tasks that tap key components of controlling air vehicles from a ground station; and (3) to conduct basic research on cognitive aspects of UAV/UCAV operator skill, both for existing UAVs and possible future UCAV designs. The simulation environment is a PC-based system that initially replicates most of the functions of the Predator Air Vehicle Operator and Payload Operator stations, but will be expanded to incorporate future experimental interface designs. It will be used to study UAV skill analysis and training issues both for existing and possible future UAV/UCAVs. The simulation uses inexpensive off-the-shelf equipment for controls and displays. The synthetic research tasks are relatively short-duration abstract tasks that nevertheless accurately reflect the cognitive sources of difficulty involved in operating UAVs. The design of the initial synthetic tasks was based on structured interviews with experienced Predator operators. Software implementations of these tasks will be distributed to DOD laboratories and universities to support research on UAV/UCAV training and interface design issues. The initial basic research studies will test the idea that prior airborne-cockpit flight experience develops air sense that cannot be obtained from ground-only training of the predator AVO. The Air Force Office of Scientific Research funds this project.

7F1.3 Collaborative Partners

United States Navy
United States Marine Corp
United States Air Force
NAWCAD
Naval Air Warfare Center Training Systems Division
Aechelon Technology
SGB Enterprises
n-vision
Photon Research Associates
Silicon Graphics
Surface Data

7F1.4 VR R & D Facilities Available

- F-16 simulators flying an integrated mission with multiple simulators and control stations in the United States, with plans for linking simulators in the United Kingdom;
- Uninhabited Aerial Vehicle training system;
- Night Vision Training System

The Distributed Mission Training (DMT) is represented by a battle scenario comprised of a two-ship of F-16 simulators and the Threat Systems Management Office (TSMO) ground-based threat simulator, linked through the Theater Air Command and Control Simulation Facility (TACCSF) at Kirtland AFB, with a two-ship of F-16 simulators and an A-10 simulator at Davis-Monthan AFB, an AC-130 simulator at Hurlburt Field, an AWACS weapons director station, and an Integrated Air Defense System (IADS) control station in San Antonio, and a view port at the Theater Battle Arena in Washington, D.C. Scenarios are flown on a common database (Nellis AFB and the Nellis Range Complex).

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Ms. Kathleen Robinette, Dr. Glenn Wilson, Dr. Joe McDaniel

7F2.1 Areas of Interest

Information Analysis & Exploitation
Collaborative Systems Technology
Human Interface Technology
Visual Display Systems

7F2.2 Current Research Projects

7F2.2.1 Adaptive Interface Technology:

The objectives of this task are to develop and evaluate interface concepts which are capable of adapting, in real-time, to the operators state. Adaptation requires the availability and understanding of highly flexible control and display devices, computational models of situation awareness, workload, and operator performance, and the ability to directly measure the operator's state using physiologic and behavioral metrics. Interface concepts produced under this task differ greatly in maturity, ranging from the integration and evaluation of helmet-mounted displays, head-level displays, localized audio, and tactile displays into prototype tactical crew stations, to the evaluation of direct electrical vestibular stimulation as a spatial display. The alternative control elements of this task are focusing on the development and evaluation of hands-free technology for interacting with ubiquitous and wearable computer systems. Such systems will be the basis for future Unmanned Aerial Vehicles (UAV) and aircraft maintenance environments. Technologies being evaluated include controllers based on head and eye tracking, speech, hand and facial gestures, brain and muscle electrical signals, and multi-modal combinations thereof. Interface concepts are evaluated on their ability to improve weapon system performance by enhancing situation awareness and the management of operator workload. These metrics tie directly into Technology Planning Integrated Product Teams (TPIPTs) deficits. In addition, this task is supporting the Defense Technology Objective Immersive Interfaces for Unmanned Vehicles (HS.23.02) which was approved by Department of Defense Research & Engineering (DDR&E) in FY98.

Technology Insertion Point: Interface concepts currently under development may be applied within crew stations involved in air-to-air and air-to-ground combat. They also have application to both Unmanned Reconnaissance Air Vehicle (URAV) and Unmanned Combat Air Vehicle (UCAV) control stations. Evaluation of interface concepts within this task typically is completed within a flight simulation environment. Interface concepts developed within this task are planned to transition into the Helmet Mounted Sensory Technology (HMST) 6.3 program as documented within the HMST roadmap. An indirect transition path is from this task, to the aerospace industry, and finally into an operational weapon system. This path is accomplished by demonstrating interface concepts to industrial representatives and

representatives of the Warfighting community when appropriate, typically following evaluation within a complex simulated environment. Wearable computer systems being developed for flightline maintenance personnel represent the near-term insertion point for alternative control technology. Preliminary field testing will be conducted in FY98 and operational systems could be fielded within a 3 year time frame. UAV control centers represent a slightly longer-term target, but one that is achievable within a 3-5 year time frame. Their ground-based, controlled environment will permit rapid insertion of Commercial Off The Shelf (COTS) components configured for USAF requirements.

7F2.2.2 Engineering Anthropometry:

Develop advanced human physical measurement and characterization technologies to increase the protection, performance and affordability of crew systems.

Technical objectives:
Developing accommodation evaluation methods, electronic databases, and tools for insertion of the technologies into computer aided design and manufacturing environments. Increase affordability of these and future systems with expanding accommodation of crew member and maintainer populations.

Technical barriers include:
The limitations of computer aided design and manufacturing tools to incorporate human physical data bases and information; visualization and analytic data distillation for the new increased volume of information; linking performance assessment with physical properties.

Task products needed that do not exist anywhere else include:

1) full body 3-D data collections and standardized measurement protocols.
2) on-line accessible and visualizable anthropometric data system.
3) step by step procedures handbooks and training manuals for fit testing and cockpit accommodation.
4) procedures handbooks and training manuals for development of anthropometric specifications for acquisition.

Technology Insertion Point:
In the short term this technology is being utilized by the Joint Primary Aircraft Training System (JPATS), F-22, Joint Helmet Mounted Cueing System(JHMCS), Helmet Mounted Sensory Technology(HMST), Joint Services Light-weight Integrated Suit Technology(JSLIST), and JPACE programs, in the specification, design and testing of systems or components. In the long term the advanced statistical methods, testing methods, data bases, and measurement methods will be useful for the Department of Defense (DoD) in: 1) making informed decisions about entry standards, 2) design and testing for the JSF, Space Plane, and any other future human occupied human system, and 3) making informed decisions about equipment logistics for troops in the field. In the future the insertion point will probably change from DoD organizations directly, to focus on the contractors who are designing the systems for the DoD. This is a result of the DoD's transition to performance based acquisition. Even now, the DoD organizations are for the most part acting as information gateways to the contractors rather than as the information recipient. It will therefore be important that the technology be transitioned to the broader engineering community, beyond just the DoD.

7F2.2.3 Ergonomics Design Tools:

Task Description:
Task 718412 includes three R&D facilities: (1) Physical Ergonomics Lab that develops dynamic physical performance data and models for more usable crew stations and maintenance workplaces; (2) Behavioral Visualization Lab that develops perceptual performance data and models; and (3) CSERIAC (Crew System Ergonomic Research Information Analysis Center), a DoD IAC that performs analysis services and transitions human factors engineering data worldwide. To develop and transition engineering tools

using ergonomics data for designers of Air Force systems, Task 718412 has developed models of physical performance (e.g. COMBIMAN and Crew Chief) and perceptual performance (e.g. Engineering Data Compendium, CASHE).

To assist the acquisition community in the design, specification, and testing of Air Force weapons systems, models and data are widely distributed (directly and via CSERIAC).

Technology Insertion Point:
This task directly supports the Crew System Engineering Design Tools DTO HS.08.06. Human performance models are a highlighted product area in the newly formed Human Effectiveness Directorate (HE). HEC plans to expand this task to integrate the division's performance data and models in support of HE's modeling & simulation, human performance, and automation areas, including 6.2 input to 6.3. In addition to performing original R&D, it will establish requirements for other HEC tasks spin-off data and products in support of these objectives. As such, this task will integrate tools in techniques in the areas of human performance modeling, functional task analysis, and cognitive modeling.

7F2.2.4 Human Sensory Feedback (HSF) for Telepresence:

Task Description:
The human-computer interface system is one of the most important factors in system effectiveness, operational integration, and long range cost of ownership. The human-in-the-loop control of these interface systems requires a keen understanding of human sensory feedback including the cognitive and perceptual factors. This task focuses on developing the technology to enhance performance and studying human factors for arm and hand interfaces to remote or synthetic environments. The objectives of this effort are: (1) to determine requirements for arm master-slave teleoperator systems (e.g. Unmanned Aerial Vehicles (UAVs)); (2) to evaluate and improve force reflecting algorithms to enhance user (e.g. pilot) performance; (3) to enhance the understanding of and technology for telepresent grasping and fine manipulation; and (4) to explore the use of virtual (synthetic) contact surfaces to improve the performance of telerobotic systems.

Technology Insertion Point:
We are developing force feedback algorithms and control algorithms to integrate into force-reflecting platforms that will be individually assessed for each mission/task. Working with the users to advance the understanding of the relationship between the operator and the remote robotic system, we will be able to successfully integrate the human's best capabilities with the best characteristics of the robotic device(s). This will result in the development of the most effective overall system for upgrading current systems and for the creation of new systems.

7F2.2.5 Operator Workload Assessment

Task Description:
Modern complex, information rich, high technology systems have vastly changed the role of the human operator. This task evolution has spawned a number of operationally meaningful concepts that are intuitively appealing and useful but have provided significant challenges to behavioral researchers in defining and measuring. Among these terms are mental workload (WL) and situation awareness (SA) which are typically used in characterizing cognitive aspects of a human operator in the context of a person-machine system. Mental workload measurement attempts to quantify the cognitive demands an operator experiences in processing information. Situation awareness generally refers to the quality of an operator's understanding about the system, the environment, and their interactions. Many new combat systems are justified on the premise that they improve situation awareness, reduce workload or both. Systems evaluators have the task of determining whether or not a given intervention intended to reduce workload and/or improve situational awareness has succeeded. This task addresses research that produces and evaluates new metrics and models for such cognitive constructs.

Technology Insertion Point:
The primary users of the products from this task have been representatives of the Test and Evaluation community. However, the need for such measures has been identified as a major need for simulation. Analytical models for the design community are also a critical need.

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- CNN's Future Watch
- USAF News
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- Popular Mechanics

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7F2.4 Lab Facilities

7F2.4.1 Alternative Control Technology Laboratory:

ACT development and applications research is conducted in Building 33 of the Crew System Interface Division of the Air Force Research Laboratory at Wright-Patterson Air Force Base in Dayton, Ohio. Included in the lab's resources are:

ISCAN RK-426TM Pupil/Corneal Reflection Tracking System Simultaneously tracks the center of an operator's pupil and corneal reflection to determine eye line-of-sight;

Flock of BirdsTM Magnetic Tracker Yields information on head position and rotation;

EVACI (Eye/Voice Aware Cockpit Interface) Uses commercial speech recognition and eye tracking systems to enable hands-free interaction with simulated front panel cockpit controls and displays;

Brain Actuated Controllers Enables control of external devices using naturally-occurring or voluntarily-produced modifications of EEG activity. These systems employ the visual evoked response (measured with scalp electrodes) to a modulated light and translate these responses into control inputs.

CyberLinkTM Records EMG and electro-oculographic signals from forehead electrodes and translates the inputs into multiple control signals.

Infrared/Sound/Touch IST SwitchTM Senses eye, mouth, or other facial activity using low-cost sensors and electronics.

Ultrasonic Microphone System Measures lip motion for a variety of control applications.

Test Environment Generation Systems Includes a wide range of displays and motion environments for the evaluation of new control systems.

7F2.4.2 Cognitive Assessment Lab

The Cognitive Assessment Laboratory is located in Building 33, room 225, in the Crew System Interface Division of the Air Force Research Laboratory at Wright-Patterson Air Force Base. The heart of the Cognitive Assessment Laboratory is the Simulator for Tactical Operations Research and Measurement (STORM) facility. The Simulator for Tactical Operations Research and Measurement is a PC-based, moderate-fidelity simulator of a ground-attack variant of the F-16. The Simulator for Tactical Operations Research and Measurement facility provides a setting with far more complexity and realism than traditional cognitive psychology tasks, yet it is more accessible and economical than high-fidelity simulation facilities. Thus, the Simulator for Tactical Operations Research and Measurement facility is an optimal in-house setting for validation of Cognitive Assessment Laboratory-developed metrics. The Cognitive Assessment Laboratory also possesses three rapidly reconfigurable booths for traditional

cognitive psychological research. These booths allow the efficient evaluation of competing theories or metric approaches with simpler laboratory tasks.

7F2.4.3 Computerized Anthropometric Research & Design Laboratory

The Computerized Anthropometric Research and Design facility is part of the Crew System Interface Division of the Air Force Research Laboratory and features a unique research team of physical anthropologists, software engineers, an electrical engineer, human factors engineers, a physician, physiologists, and statisticians. The Computerized Anthropometric Research and Design facility has generated one of the largest anthropometric databases in the world, consisting of:

- A normative database of 3-D surface scans of over 1,500 human heads;
- An aircrew database of 3-D whole body scans in 3 postures;
- Three-dimensional surface data of head/equipment interface and associated fit criteria;
- International data from more than 50 large-scale traditional anthropometric surveys;
- A cockpit accommodation database with accommodation predictive algorithms for 3 aircraft and additional aircraft are being added to include the entire Air Force inventory within the next 3 years.

7F2.4.4 Flight Psychophysiology Laboratory

Computerized systems are available for recording and analyzing psychophysiological data. In addition, two ambulatory flight recording systems are utilized. One is worn by the operator and provides eight channels of data while the other uses a laptop computer and can record 30 EEG channels as well as heart rate, eye blink, and respiration data. Two custom-designed psychophysiological assessment systems have been developed in this laboratory. The Psychophysiological Assessment Test System (PATS) records up to 16 channels of data, presents cognitive tasks and provides numerous editing and analysis capabilities. The Workload Assessment Monitor (WAM) analyzes heart, eye, respiration, and seven EEG channels on-line and provides continuous estimates of operator workload.

7F2.4.5 Physical Ergonomics Laboratory

Research is performed in the PEL's five bays where separate work tasks are simulated. The diverse and changing nature of USAF jobs requires custom-made measurement equipment, such as state-of-the-art computer-based data collection systems for simultaneous, real-time recording of multiple performance-related variables.

This facility has a network of state-of-the-art computer workstations used to develop ergonomic models and to advance methods for visualizing the physical performance in the workplace. A network of PCs and workstations (some provided by industry partners whose customers use these human models) is used to develop human model software.

Accurate analysis of workplaces requires accurate "electronic mockups." The PEL's new coordinate measuring machine (below) quickly and accurately gathers 3-D coordinates to build CAD models of the workplace. COMBIMAN (COMputerized BIomechanical MAN-model) can then assess effectiveness of proposed upgrades, as we have recently demonstrated for aircraft upgrade programs.

The Physical Ergonomics Lab has massive databases describing hundreds of thousands of measures of male and female physical performance. These include male and female pilot strength data, and tool torque and materials-handling data. Such data are used to evaluate the physical accommodation in a cockpit for fit, reach, and strength as a function of flight clothing and harnessing, as well as visual accessibility.

Expanding the scope of ergonomic models, PEL is beginning to add "eyes and ears," that is, to incorporate features of cognitive and perceptual ergonomics evaluation into the models. The expertise of the human model will be enhanced with a new capability to guide the designer toward system changes that improve the physical accommodation of the human operator or maintainer, including case-based reasoning.

To service business and industry, CSERIAC (Crew System Ergonomics Research Information Analysis Center) distributes data, reports, and computer models from the Physical Ergonomics Lab. Via CSERIAC, it is possible for businesses and industry to access the unique PEL facilities for custom research.

7F2.4.6 Synthesized Immersion Research Environment

The Synthesized Immersion Research Environment has been designed to support research and development of advanced crewstation concepts well into the twenty-first century. The Synthesized Immersion Research Environment's visual display capability is unique in its large field-of-view, high-resolution characteristics, and is capable of displaying any scene generated by a general-purpose graphics system. Because of this versatility, the facility has applications that extend far beyond advanced crewstation interface design. For example, the Synthesized Immersion Research Environment can support research in defense and industry-related areas. A specific example of this is the visualization, in SIRE, of a neurosurgical suite located in a local medical center. The Synthesized Immersion Research Environment is currently supporting international, cooperative research and development programs with the French and British governments. This work is leveraging the development of advanced multi-sensory cockpit displays and controls developed by each country. Products of these efforts include advanced adaptive interface concepts as well as quantified weapon system performance improvements within flight simulation of air-to-air and air-to-ground combat. The SIRE currently contains the only crew station combining U.S. and French control and display devices in the United States.

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7F3 - ARI - Army Research Institute

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Research start date: Research in the area of the use of virtual environment technology for soldier training began in October 1993.

7F3.1 Areas of Interest

Use of VR/VE for dismounted Infantry training.

7F3.2 Current research projects

Virtual Environment Research for Infantry Training and Simulation. The objective is to develop, integrate, demonstrate, and evaluate technologies, techniques, and strategies for using virtual simulations for individual, leader and small unit training, mission rehearsal, concept development, and test & evaluation. Emphasis is being placed on developing the capability within Virtual Environments to conduct night, MOUT (Military Operations in Urban Terrain) and contingency operations.

7F3.3 Results achieved to date

Initiated a program of experimentation to investigate behavioral sciences issues in the use of VR for military training in 1992. Following an initial analysis of the task requirements for dismounted soldier training, and a review of previous VR training research, four experiments were conducted to investigate interface effects on the capabilities of participants to perform simple tasks in VR. Variables investigated included the type of control device, amount of task practice, stereoscopic vs. monoscopic helmet-mounted displays (HMDs), and type of display device (monitor, Boom, or HMD). Three experiments were performed that addressed the effectiveness of VR for teaching route and configuration knowledge of large buildings, and the transfer of this knowledge to the real world. The results of these experiments led to a program of basic research on distance estimation in VR. The next phase of the research investigated the use of VR to represent exterior terrain for training both land navigation skills (identifying landmarks and learning routes) and terrain knowledge. Finally, research was conducted investigating the use of VR for training more complex tasks. This included experiments examining the effects of self representation on performance, the training of two-person hazardous materials teams, and distributed team training in underway. Overall, the program has conducted 16 experiments involving over 600 human subjects. Knerr

et al. (1998) provides an overview of the results of the first phase of the program (1993 – 1998), along with recommendations for the use of VR for dismounted soldier training.

Beginning in 1999, increasing emphasis within the program is being placed on the development of technologies and techniques for the training of Infantry leader tasks.

7F3.4 Collaborative partners

US Army Simulation Training and Instrumentation Command
US Army Research Laboratory, Human Research and Engineering Directorate
US Army Research Laboratory, Computer and Information Sciences Directorate
US Naval Air Warfare Center Training Systems Division.
University of Central Florida Institute For Simulation and Training

7F3.5 Literature prepared by researchers

7F3.5.1 ARI Reports

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7F3.6 VR R&D laboratory facilities available

- Silicon Graphics Workstations including an Onyx RealityEngine Rackmount System (3 Graphics Pipes, 8 CPUs, 12 RMs, MCO), an Onyx RealityEngine Deskside (4 CPUs, 4 RMs, MCO), an Onyx RealityEngine Deskside (2 CPUs, 2 RMs) a Crimson RealityEngine Deskside (2 CPUs, 4 RMs, MCO), an Octane (2 CPUs. OCO), and several High Impact, O2, Indy, and Indigo Systems.
- Evans and Sutherland ESIG 2000 dual channel image generator
- SIMNET 8-channel image generator and M1A1 Tank Simulator
- Numerous Networked PCs
- Virtual Research V8 HMD (2)
- Virtual Research VR4 HMD (3)
- Virtual Research Flight Helmet (2)
- VPL EyePhones
- Fake Space Labs, high resolution 2-color BOOM
- CrystalEyes (4)
- Howlett CyberFace II
- Ascension Flock of Birds tracker, extended range with 8 sensors
- Ascension Flock of Birds tracker, extended range with 2 sensors
- Ascension MotionStar tracker, extended range with 16 sensors
- Polhemus trackers with multiple sensors (3)
- LogiTech Acoustical trackers (2)
- Crystal River Convolvotron
- IST ChordGloves™ (4 pairs)
- IST VE Motion Treadmill
- Mirage Display System
- Auto Cad
- Alias
- ElectroGIG
- GMS
- GRASS
- MultiGen
- Neo Visuals
- S-1000
- Strata Vision-3D

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7F4.1 Areas of Interest

1. Virtual Reality in Aerospace Training
2. Virtual Reality in Medicine
3. Virtual Reality in Military Operation Other Than War
4. Virtual Reality in Data Visualization
5. Intelligent Computer-Aided Training

7F4.2 Current Research Projects

7F4.2.1 The Hubble Space Telescope:

A major project that replicated all relevant repair and maintenance scenarios for the Hubble Space Telescope mission (STS-61) was completed in the fall of 1993. Over one hundred members of the flight control team were trained with this system, providing an opportunity to demonstrate the full potential of virtual environment technology in training.

7F4.2.2 Shared Virtual Environments:

Collective training, concurrent engineering, and scientific data analysis can all be supported through shared virtual environments. We have developed the capability to share, in "real" time, virtual worlds between distant sites. This has enabled us to begin to explore the potential of VE technology for building a team, even though the members may be geographically dispersed.

7F4.2.3 Knowledge Acquisition:

As NASA personnel frequently perform tasks that are primarily procedural in nature, this tool is devised for modeling such procedures of a mission or task and generating hierarchical reports as part of a process capture and analysis effort. Historically capturing knowledge has proven to be one of the greatest barriers to the development of intelligent systems. In essence, TARGET is one of the first tools of its kind, commercial or institutional, to short circuit what would otherwise be a tedious, drawn-out undertaking.

Systems such as TARGET have the potential to profoundly reduce the time, difficulties, and costs of developing knowledge-based systems for the performance of procedural tasks.

7F4.2.4 Task Analysis Rule Generation Tool (TARGET)

TARGET (Task Analysis Rule Generation Tool) is a graphical interface tool used to capture or preserve procedural knowledge and translates that knowledge into a set of CLIPS expert system rules. The TARGET concept is based on a knowledge acquisition tool developed by the Naval Systems Training Center, called VISTA (Visual Interactive System for Task Analysis). TARGET is currently written in 'C' and is developed for the Microsoft Windows 3.0 platform, with future platform ports to Macintosh and X-Windows.

7F4.2.5 ScienceSpace

Project ScienceSpace is an ongoing series of controlled experiments to assess the potential impact of Virtual Reality in science education. We use the term ScienceSpace to refer to the virtual worlds in which these experiments are conducted. The primary focus of the project is to determine whether students can demonstrate a better understanding of scientific concepts after having a direct, interactive VR experience with the phenomena in question.

The first environment, NewtonWorld, is now in use. This artificial reality allows students to experience Newton's three laws in an idealized environment that they can control. An initial study of student usability is complete, and we are preparing for the first learning-transfer study which will begin shortly. A second environment, MaxwellWorld, This world has been designed to enable the examination of the nature of electrostatic forces and fields, to aid students in understanding the concept of electric flux, and to help them empirically "discover" Gauss's Law. A third virtual environment, PaulingWorld, allows one to examine the structure of both small and large molecules from any viewpoint and in a number of single or mixed representations.

7F4.2.6 Assessing a Virtual Reality Surgical Skills Simulator

The Institute for Defense Analyses (IDA) was contracted to perform a military standard task analysis of laparoscopic cholecystectomy, and to study the effectiveness of a virtual reality surgical skills simulator as a tool for surgical training and as a method for recording psychomotor behavior. This report describes the purpose of the study, its design, initial results, and implications for the field of medical education.

7F4.2.7 Virtual Reality in Surgical Education

Laparoscopic surgery is a new operative technique which requires the surgeon to observe the operation on a video-monitor and requires the acquisition of new skills. VR simulation could duplicate the operative field and thereby enhance training and reduce the need for expensive animal training models. Because a surgical procedure consists of a series of tasks and each task is a series of steps, we will plan to create two important tasks in a VR simulator and validate their use. Our hypothesis is that VR in combination with fuzzy logic can educate surgeons and determine when they are competent to perform these procedures on patients.

7F4.2.8 Virtual Reality in Military Operation other than War

The basic project components include:

- Conducting basic research on the level of fidelity necessary to (1) accomplish a pre-defined level of training transfer and (2) communicate non-verbal cues (facial expressions, gestures, body postures, interpersonal separation) associated with foreign cultures;
- Integrating intelligent agents into the virtual environment to (1) function as coaches/mentors for trainees, (2) play the role of indigenous personnel, and (3) replace missing team members;

- Developing a means of sharing virtual environments over long distances through the use of Distributed Interactive Simulation (DIS) protocols and moderate-bandwidth communication channels;
- Enhancing the computational infrastructure underlying virtual environments to (1) improve the speed of graphics rendering, (2) support rapid importation of terrain databases, and (3) enable training personnel to both build and maintain complex virtual environments; and
- Building, in a very short time period, a training application designed to equip a multi-service task force with the skills and knowledge necessary to conduct an Operation Other Than War (e.g., humanitarian relief, police actions) in a foreign land where they will physically assemble for the first time.

7F4.2.9 Virtual Reality in Data Visualization

During the past few years, considerable attention has been given to a collection of high performance computing and communications technologies directed at "data visualization. This rapidly-evolving group of technologies enables the examination of large information spaces, and offers the potential of new and powerful mechanisms for identifying subtle patterns in data-patterns that may lead to new and crucial discoveries heretofore eluding a specific research community. The proposed computing and communication infrastructure development at the University of Houston-Downtown will support faculty in their research by providing powerful and accessible means for exploring and sharing their data. There are four specific approaches that will be implemented to enhance the ability of the university's scientists and engineers to access, explore, manipulate, and comprehend the many information spaces of today and tomorrow.

7F4.3 Collaborative Partners

University of Houston (Lead Organization)
George Mason University
LinCom Corporation
Lockheed Martin Federal Systems, Inc.
University of Houston-Downtown
University of Pennsylvania
Joint Readiness Training Center (Ft. Polk, Louisiana)
National Aeronautics and Space Administration/Johnson Space Center (Houston)
U.S. Air Force Armstrong Laboratory (Brooks AFB, TX)
U.S. Army Research Institute (Alexandria, VA; Orlando, FL; Ft. Rucker, AL)
U.S. Navy Naval Command, Control and Ocean Surveillance Center (San Diego)
U.S. Navy Naval Personnel Research and Development Center (San Diego, CA)
U.S. Navy Medical Research and Development Command (Bethesda, MD)
MultiGen-Paradigm Inc.
National Science Foundation
Office of Naval Research
Walden 3-D
University of Central Florida
Institute for Simulation and Training
University of Pennsylvania
Transom

7F4.4 VR R&D Facilities Available

VETL occupies approximately 8,000 gross square feet of space and houses the following equipment:

Computers

(1) Silicon Graphics Onyx RE3 Infinite Reality Graphics Workstation (rack-mounted, 4-200 MHz CPUs, 768 Mb RAM, 3 graphics pipes 1 RM6-64 and 1 DG4-2 per pipe, 4 Gb mass storage, CD-ROM drive, 4-mm DAT drive)

(1) Silicon Graphics Onyx i-station RE3 Infinite Reality Graphics Workstation (1-250 MHz CPU, 128 Mb Ram, 1 RM6-16, 1-DG4-2, 2 Gb mass storage)

(1) Silicon Graphics Onyx2 Infinite Reality Deskside Workstation 2 R 10,000 (195Mhz) CPU's, 4Mb Cache, 512 RAm, 9.1GB mass storage, 2 raster managers.

(1) Silicon Graphics Onyx RE2 Graphics Workstation (4-150 MHz CPUs, 256 Mb RAM, 2 Gb mass storage, 2 RM4-16, Multi-Channel Option Board)

(1) Silicon Graphics Octane, Dual R 10,000 processors (250Mhz), 1Mb cache, 4Mb Texture Memory, 4 GB Systems disk.

(1) Silicon Graphics Origin 200 server, 1R 10,000 Processor, 9.1 GB memory.

(7) Silicon Graphics O2 Workstations.

(1) Silicon Graphics Indigo Maximum Impact Graphics Workstation (250 MHz CPU, 192 MB RAM, 4Mb texture memory, CD-ROM Drive, 2Gb mass storage; ICO board for multi-channel output)

(1) Silicon Graphics Indigo Maximum Impact Graphics Workstation (250 MHz CPU, 192 Mb RAM, 4 Mb texture memory, CD-ROM Drive, 2 Gb mass storage each)

(2) Silicon Graphics Indigo High Impact Graphics Workstation (200 MHz CPU, 128 Mb RAM; 1 w/ 250 MHz CPU, 64 Mb Ram; 2 Gb mass storage each)

(1) Silicon Graphics Indigo Extreme-2 Graphics Workstation

(2) Silicon Graphics Model 320/VGX Graphics Workstations

(1) Silicon Graphics Model 85/GTX Graphics Workstation

(8) Silicon Graphics Indy Graphics Workstations

(2) Sun Microsystems SparcStation 1 Workstations

(1) 9 Gb mass storage system

(1) 8-mm DAT tape drive

(20) Personal Computers (Macintosh and PC)

(1) Power Macintosh G3 with Applevision monitor

Visualization Equipment

(1) CAVE System (4-Electrohome 8500T, P43 phoshor, video projectors, Crystal Eyes Stereographics system, back-projection screens, floor, and mirrors (10-foot by 10-foot by 10-foot) housed in a 50' x 35' x 14' room)

(2) Collaborative Workbench visualization systems.

(4) Flogiston Personal Motion Platform (2-3 degress-of-freedom and 2-6 degrees-of-freedom) equipped with chairs conforming to the modified neutral buoyancy posture of the human body.

(2) Electrohome Marquee 8500T with P43 phosphor video projectors.

(3) Virtual Research VR4 i head-mounted displays

(1) Virtual Research EyeGen3 Display

(1) Kaiser VIM Display

(2) VPL Research Eyephone LX (1 has been remounted.)

(1) VPL Research Eyephone HRX

(1) Hughes Training Prototype Head-Mounted Display

Haptics

(1) Chair w/attitude and translation controllers

(2) Silicon Graphics SpaceBall=81 systems

(1) Virtex CyberGloveTM.

(1) Rutgers/Burdea Force Feedback Glove (thumb and three fingers)

(8) VPL Research DataGlove Model 2 plus Accessories (plus 3 controllers)

(1) Tele-Tac Tactile Feedback Glove

(1) VPL Research RB2, Model 2 Virtual Reality Systems (includes Polhemus IsoTrak Systems and interfaces for DataGloves and Eyephones)

Tracking Systems

(4) Polhemus FastTrackTM Magnetic Position Tracking Systems.

(1) Ascension Flock of BirdsTM Magnetic Position Tracking System with 4 receivers, 2-6d spacemouse.

Sound Systems

(1) Crystal River Acoustetron II System .

(1) VPL Research AudioSphere (Convolvotron) System.

Mass Storage

(2) 9 Gb mass storage systems

(1) 6-tape, 4-mm DAT automated backup system

(1) 8-mm DAT tape drive

Supplemental Equipment

(1) Xerox DocuPrint C55mp Color printer

(1) Futix Pictography 3000 Color Printer

(1) Agfa 2400 dpi color scanner

(2) Hewlett-Packard LaserJet Printers

(1)Apple Laserwrite

(1) Apple Color InkJet Printer

(1) NEC PC-VCR

(1) JVC SVHS VCR

(1) Sony Dual Hi-8 VCR

(2) RCA 27" Monitors

(1) Toshiba VCR

(1) Sanyo 25" monitor w/ built-in VCR

(1) Yem CVS-980 Scan Converter

(1) Sony VPH-1271Q Video Projector

(1) Kodak Carousel 35 mm Projector

Miscellaneous software and non-capital equipment and supplies

3D Graphics Software:

Alias Wavefront (9 licenses)
MultiGen (2 licences)
Cosmo Suite
Radiance EZ-3D (4 licenses)

Chaos Tools LightWave 3D (2 licenses)
Surface Modeler (SSM) by NASA

VR Programming Software:

Performer 2.0
Lincom Corporation VrTool (comprehensive Ve development suite)
Vega (tm) from MultiGen-Paradigm Inc.
NSPNet

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7F5 - Naval Air Warfare Center, Training Systems Division (NAWCTSD)

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7F5.1 Areas of Interest

VEs for the acquisition and use of spatial knowledge;
Haptics (virtual touch and feel), cross-sensory display substitution, depth perception;
Modeling of individual differences in spatial cognition at the individual and team level.
Demonstrate VE technology for officer of the deck ship handling training to determine the viability of VR technology as a training tool for this and other tasks.

7F5.2 Current Research Projects

7F5.2.1 Virtual Environment Training Technology (VETT):

The Virtual Environment Training Technology (VETT) program is an applied research and development program (6.2) sponsored by the Office of Naval Research (ONR) and performed jointly in-house at NAWCTSD as well as through a collection of contractors and academic institutions. VETT's objective is to develop, demonstrate, and evaluate virtual environment technologies for Navy VE system applications. This involves research and development efforts in a number of areas including: side effects from virtual environment exposure, haptic interface development, instructional approaches to training, information visualization, behavioral modeling, metaphor design, performance measurement, usability, etc.

7F5.2.2 Conning Officer Virtual Environment (COVE):

COVE will provide technology to the Surface Warfare Community to train or refresh "seaman's eye". It will be a flexible, portable unit that can be used in the schoolhouse and deployable onboard ship. Central to its concept is the extensive integration of new intelligent tutor techniques with state-of-the-art virtual environments (VE). COVE is intended to produce a unique blending of the two emergent technologies, in such a way as to vastly increase the training effectiveness that neither would achieve alone.

7F5.2.3 Virtual Environment for Submarine Ship Handling and Piloting Training (VESUB):

The goal of the Virtual Environment for Submarine Ship Handling and Piloting Training (VESUB) is to develop, demonstrate, and evaluate the training potential of a stand-alone virtual reality-based system for

OOD training and to integrate this system with existing Submarine Piloting and Navigation (SPAN) training simulators. A head mounted display will be used to provide the trainee with a simulated 360 degree visual environment containing all of the required cues associated with harbor and channel navigation as well as varying geographical and environmental conditions. Voice recognition and synthesis will be used to provide communications training. Once the stand-alone virtual reality system has been demonstrated and evaluated, it will be interfaced with a SPAN trainer and its team training effectiveness will be evaluated. If proven effective, specification for the stand-alone and integrated OOD training systems will be transitioned to the submarine training community for acquisition of operational systems.

7F5.3 Results Achieved to Date

7F5.3.1 VETT:

The Naval Air Warfare Center Training Systems Division (NAWCTSD) has conducted a coordinated program of research to address the application of virtual environments to training. The purpose of the Virtual Environment Training Technology (VETT) program was to develop, demonstrate, and evaluate virtual environment technology for training applications. The VETT program included five primary work areas: (1) VETT Enabling Research for the Human Operator (ERHO); (2) Haptic Interface Design and Evaluation; (3) VETT Side Effects R&D; (4) Training Effectiveness Research; and (5) Testbed Development and Utilization.

7F5.3.2 COVE:

Currently the COVE system is designed with a DDG-51 class destroyer and a AOE-6 class supply ship for the purpose of simulating the UNREP evolution. During the upcoming year, visits are planned to fleet units to verify the simulation and conduct experiments with the intelligent tutor. Also planned are studies using a helmet mounted display to fully immerse the user in the simulation.

7F5.3.3 VESUB:

An exploratory system, developed under the Research, Development, Test and Evaluation 6.2 Virtual Environment Training Technology program was used to provide a context for over 25 submarine subject matter experts to articulate additional requirements for the 6.3 technology demonstration systems. Three contracts were awarded to accomplish the goals of the effort. They were: 1) a requirements determination contract, which was completed and documented in NAWCTSD Special Report 96-002; 2) a system development contract; and 3) a subject matter expert contract for independent verification and validation of system software, courseware, and instructor/operator station design. An Implementation Planning Group, consisting of active duty submarine personnel and government engineers and instructional developers was also established to provide guidance for the project. The first system database was delivered in Dec of 96. Formative evaluations of system interactions began at that time. During FY97, formative evaluations of the system continued and the final version was completed by early FY98. Training effectiveness evaluations (TEEs) were conducted at two Naval Submarine training sites. The results of the TEEs (see Project Reports) and experience gained throughout the project are being used as the foundation for the VESUB 2000 procurement specifications.

7F5.4 Collaborative Partners

ONR (Office of Naval Research)
NPS (Naval Post Graduate School)
NRL (Naval Research Laboratory)
NAMRL (Naval Aerospace Medical Research Laboratory
SWOS (Surface Warfare Officer School)

ARI (Army Research Institute
STRICOM (Simulation, Training, and Instrumentation Command
USAFA (United States Air Force Academy)

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7F6.1 Areas of Interest

The design of the large-scale virtual environment (LSVE) network software architecture, web-based interoperability, cross-platform VE toolkits; rapid 3D virtual environment construction; spatial sound for the improvement of performance and training in the virtual environment; virtual environment evaluation for its utility in training; fidelity requirements for wayfinding in the virtual environment; software architectures for computer-generated virtual environment characters and semi-automated forces; modeling of plan-based actions for intelligent agents in a simulation; autonomous behavior for simulated humans and real or simulated military vehicles; the Department of Defense's High Level Architecture for virtual environment interoperability; runtime interface (RTI) and next-generation RTI; human body tracking technologies to provide a natural and immersive interface to networked virtual environments; articulated body kinematics and dynamics; inertial motion tracking, locomotion devices, human modeling in the VE.

7F6.2 Current Research Projects

7F6.2.1 Networked Virtual Environments:

NPSNET-V - A portal into a dynamically extensible, networked virtual environment;
Large-Scale Virtual Environments - The Network Software Architecture;
Bamboo - A Platform and Language Independent Mechanism for Enabling Dynamically Reconfigurable Applications.

7F6.2.2 Computer-Generated Autonomy:

Explorations of and Architectures for Networked, Agent-Based Adaptive Simulation;
Army Game Project.

7F6.2.3 Technologies for Immersion:

Inertial Motion Tracking Technology for Inserting Humans into a Networked Synthetic Environment

7F6.2.4 Human-Computer Interaction:

Virtual Environment Spatial Knowledge Training & Acquisition;
Virtual Environment World Building

7F6.3 Collaborative Partners

US Navy Modeling & Simulation Management Office (N6M)
US Army Modeling and Simulation Office (AMSO), FA-57 community
US Army National Simulation Center - FA-57 community
US Marine Corps Combat Developments Center, Office of Science & Innovation, MOS-9065
The Army Research Office
The Assistant Secretary of the Army for Manpower & Reserve Affairs
The Office of Naval Research
The Defense Modeling and Simulation Office (DMSO)

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7F7.1 Areas of Interest

Immersive Simulation Technologies (IST) - This research area includes the Individual Combatant STO and the Virtual Emergency Response Training System (VERTS) along with other head-mounted and voice I/O technology.

7F7.2 Current Research Projects

Objective:

Develop a High Level Architecture (HLA) compliant Individual Combatant (IC) simulation system across the Research, Development and Acquisition (RDA), Advanced Concepts and Requirements (ACR), and Training Exercise and Military Operations (TEMO) domains.

This DTO will refine RDA, ACR, and TEMO simulation requirements for individuals and small units, and create a multisensory, real-time networked simulation of the battlefield that immerses the individual combatant in three-dimensional geographical space using virtual reality technologies. A dismounted infantry computer generated forces capability will be developed to support up to a platoon of dismounted entities. Coordination of efforts is essential with the MOUT ACTD, Land Warrior (LW), Future Close Combat Tactical Trainer Dismounted Infantry (CCTT–DI) P3I upgrades, USMC's Small Unit Tactical Training (SUTT) ATD, Objective Individual Combatant Weapon (OICW) and DARPA's small-unit operations (SUO) program to support the modeling and simulation (M&S) requirements for those programs.

7F7.2.1 Virtual Emergency Response Training System (VERTS):

This program is developing, demonstrating, and fielding concept systems for use in training soldiers to respond to natural and man-made homeland emergencies. These immersive virtual systems use state-of-the-art technologies for motion tracking, visualization, and interaction with a synthetic representation of real environments.

7F7.2.2 Modeling and Simulation Defense Technology Objectives:

The Defense Technology Area Plan (DTAP) and Defense Technology Objectives (DTOs) are major elements of the DoD Science & Technology (S&T) Strategic Planning Process. The Information Science Technology (IST) area is one of several focus areas under the DTAP. Modeling and Simulation (M&S) is one of several sub-areas under the IST Technology Area. The DTOs listed below are part of the Modeling & Simulation (M&S) Sub-area:

- DTO IS.10 - Simulation Interconnection (DTO Manager: Gary Yerace)
- DTO IS.11 - Simulation Information Technologies (DTO Manager: Gary Yerace)
- DTO IS.12 - Simulation Representation (DTO Manager: Gary Yerace)
- DTO IS.40 - Individual Combatant and Small-Unit Operations Simulations (DTO Manager: Paul Dumanoir)

7F7.3 Milestones:

- FY2000: Develop prototype virtual environment night vision capability and voice recognition system. Evaluate and refine MOUT virtual environment training methods. Develop prototype advanced control system for locomotion simulator. Evaluate and refine tracking systems for both human and weapon within the virtual, constructive, and live environments. Evaluate geometric pairing solutions for IC indirect fire instrumentation systems.

- FY2001: Develop prototype gesture recognition system. Evaluate effectiveness of night operations training. Incorporate intelligent tutoring capability into preliminary small-unit leader trainers. Evaluate and provide an operational assessment of USMC interface improvements. Prototype image processed aim point determination capability for IC direct- and indirect fire instrumentation systems.

- FY2002: Develop hardware/software simulations with enhanced synthetic battlefield capabilities. Implement on low cost platform and evaluate training effectiveness. Goal is a 25% improvement in leader performance on target tasks, relative to field exercises.

7F7.4 Collaborative Partners

US Army Soldier and Biological Chemical Command (SBCCOM)
US Army Research Institute (ARI)
US Army Research Laboratory (ARL)
US Marine Corps (USMC)

8.0 - Conclusions

The basic characteristic of virtual reality consists in immersing one or more subjects in a computerised environment. To make this immersion possible, both sensing and moving organs must be connected to specific interfaces. Furthermore, it is necessary to permanently locate the human body and its segments in the real world to position them in the virtual world. As a result, let us review the various human organs and the interfaces that are used for immersion. Then, we shall deal with such issues as environment sharing and immersion psychological acceptability in those synthetic environments.

Following this, we shall deal with the military applications by studying how virtual reality techniques are currently implemented.

8.1 Immersion

8.1.1 Visual Immersion

Two aspects must be considered: image contents on the one hand, and the means used to display these environments on the other hand.

Concerning the first issue, considerable improvements have been achieved during the past three years. It is now possible to achieve very realistic geometric models representing either objects or landscapes. Associating photorealistic structures to the currently available resolutions (of the order of 50 cm for instance) increases the realistic appearance of the so-created objects. Though humanoid recreations in virtual environments are also available, it remains however necessary to improve the authenticity level of their behaviour.

Concerning the display means, improvements are also drastic. Multiple giant-size screens make it possible to create wide immersion spaces where several subjects can move simultaneously. Such spaces called CAVEs, are now available with a display capability on 6 faces. However, these systems are still fairly expensive and require very huge infrastructures. In addition, despite a very realistic rendering for a group of persons standing in such spaces, only one subject can drive the image. While these systems are well suited to the exhibition world, they can also be used in simulations where large spaces are involved, like steering a ship, moving around in a factory or climbing a mountain. In a number of cases, it is not necessary to wear stereoscopic vision glasses. This is applicable for instance to the command bridge simulator of the Naval School of Brest. Similarly, though this simulator is not actuator-driven, movement feedback is very noticeable. The immersion tolerance time in such systems is long, which is not true for those systems using a virtual reality helmet.

In some applications, it is worthwhile giving back the stereoscopic vision to the subjects immersed in these CAVE-type systems. The various glasses available on the market provide good results and the immersion tolerance time is several hours to be compared with 20 to 30 minutes maximum with a helmet. The use of glasses is very satisfactory on workbenches that are well suited to engineering offices during design phases, but also for training on workstations like small work-piece machine-tools. This type of tool is also attractive to build dynamic terrain models or for real-time military drill monitoring by a general staff for instance (assessment carried out in Germany).

In this latter case, some improvements still remain to be accomplished to transmit the data gathered in the actual field to the virtual objects.

In addition to these glasses designed to watch a screen at the same time as the actual environment, there are semi-transparent glasses display systems which make it possible to see the actual environment while projecting such information as charts or orders. These enhanced reality tools

feature attractive applications in the course of actual missions like training to first aid gestures by remotely practised medicine onboard ships or police operations.

The latter display mode applies to virtual reality helmets. Though noticeable developments have been achieved, in particular to decrease weight and cost, these systems still feature major drawbacks such as the lack of sufficiently large visual field, an operating tolerance which seldom exceeds half an hour and eye fatigue problems.

8.1.2 Acoustic Immersion

3D sound reproduction systems are still cumbersome and relatively costly. They are mainly used to create enhanced reality. For instance, each perceived sound direction corresponds to a specific speaker (control tower, friends, co-pilot). In most cases, a conventional stereo sound is enough to restore the illusion of a real sound environment. For large spaces, another solution would consist in fitting the room with more than two sound sources.

8.1.3 Taste and Smell Immersion

Concerning taste, which may be salty, sweet, sour and bitter, there is currently no interface capable of exciting taste buds.

Concerning smell, some odour dispensing systems are now available, working in accordance with the proceeding of a scene where a subject is immersed. These are genuine smells to be stored in a box and renewed after use. This does not apply to visual and acoustic environments which can be stored on a computerised media like a CD-ROM. The only parameter which can be stored is the control signal sent to the system to release such or such smell at a given time. However, there are today only a few applications in this field except in the show-business or marketing worlds. Yet this may be attractive in some simulations, for instance to release fire or oil smells that are important information sources in real situations.

8.1.4 Haptic Immersion

Hand immersion, despite the emergence of artificial feel arms capable of six degrees of freedom like the PHANTOM, still features a lot of outstanding problems. For instance, few or no systems make it possible to use both hands. A smart solutions would consist in immersing the proximal section of the tool or the control used by the subject with the subject himself. Concerning the other parts of the body, the problems are far greater and call for two separate paragraphs respectively dealing with locomotion and tracking. It must be recalled that there are few interfaces that can restore feelings on the thorax for instance, unless very cumbersome clothes are used. In addition, it is currently quite impossible to simulate feelings relating with changes in gravity. This is also true for such feels as soaking.

8.1.5 Locomotion

As soon as one wants to move in wide volume simulation spaces, he must be able to move as naturally as possible and feel in the lower limbs the sensations caused by ground irregularities. Experimental systems exist. For instance, the Utah University operates a moving treadmill in association with an artificial feel arm worn on the ankle. Recently (Noma et al 2000), an active floor was developed which reproduces moderate curves and changes depending on the scene displayed. However, to be fully efficient, these systems must be completed by efficient spatial locating devices which do not impair any move. This is what we are going to study now.

8.1.6 Spatial Location

Permanent spatial location remains an issue which is still to be greatly improved. As a matter of fact, the currently used electromagnetic systems of the acoustic, optical or mechanical Polhemus type are

most often cumbersome and restrictive for immersed subjects' mobility. If the systems are to be carried by the subject, the equipment remains heavy. Among the latest achievements, one can mention the Ascension MotionStar @ tracking which is a piece of clothes fitted with 20 magnetic sensors located at critical points of the human body, a portable computer and artificial feel devices. The whole system is connected to a helmet. While solutions exist, spatial location in large spaces is also to be improved.

8.1.7 Environment Sharing

With such tools as CAVE or workbenches, this is getting available but for the time being, only one subject can drive the pictures. In both environments, all subjects are physically present at the same place and at the same time. Remote environment sharing is also possible; representing each subject in the environment remains most often elementary. Some systems based on several video cameras recording and the processing of body position sensors yield promising results though little widespread. However, in a number of situations, for instance a battle-tank crew, these systems are not suitable, each crew member receiving an image depending on the interfaces made available to him on his own display system.

8.1.8 Psychological Acceptability

Due to the possibility of physical troubles such as nausea, headaches, eye fatigue or physical fatigue caused by equipment weight, immersion is not always well accepted by the subjects. However, after practising a familiarisation period and if immersion sessions are of about 20 – 30 minutes, virtual reality is generally as well accepted as the use of the conventional cabin-type simulators. Another aspect applies to perception of actions carried out in virtual environments: the participants react as in a video game, loosing the notion of their acts' consequences. When such actions are transmitted to the actual terrain, the participants may not be aware of them until the time when they must assume their responsibilities concerning the real consequences. Serious psychological traumas may then appear, which was called the Ender's syndrome (from the novel "Ender's game" by Orson Scott Card).

8.2 Military Applications

During the past five years, virtual reality applications in the military environment have become more and more numerous and involved both weapon systems design / assessment and training as well as mission preparation and execution. In addition, said applications affect the Army, the Air Force, the Navy, Staffs and Services all together.

At the level of new combat system development, a policy is already in force in the United-States for the use of virtual environments to design, test and assess the future systems and virtual prototypes are being surveyed for the year 2010 systems. In the meanwhile, the industry increasingly uses virtual reality tools such as the workbench to design its future products. This is more especially widespread in the automotive industry. It is now becoming possible to modify in real time the shape of a car taking into account the remarks made by engineers who may be more and more remotely located on a geographical viewpoint.

Learning and training applications are today the most numerous. Nearly all the virtual reality tools available on the market are used by them: projection on multiple giant-size screens in a large size bridge in the Navy both at the Naval Postgraduate School of Monterey and the Naval School of Brest. Similarly, the Office of Naval Research is currently developing virtual training environments using virtual pedagogic agents who interact with two students. The latter are wearing virtual reality helmets which enable them to be immersed in a ship environment. Both examples are interesting because they highlight the various virtual reality tools operating methods. The second example is based on a projection of the virtual environment in a helmet; everything is virtual. The first example, physical reproduction of a bridge, simply casts 3D environments to a screen.

This type of use is commonplace in aeronautics. In-between are found simulators which merge physical data with a virtual reality helmet. This is the case for the German Stinger simulator for instance, or for the French parachute simulator. Concerning the studies in progress, the use of glasses is being considered for instance to virtually see the inside of an actual mine by watching it in the field. Generally, (land, air, sea) vehicle simulators are well suited to the use of virtual environments; conversely, this is more difficult for the infantryman even if CAVE-type systems are used, by the Marines for instance.

Concerning mission preparation, some achievements exist which are still facing great difficulties, to have the same virtual space shared by several combatants on the one hand, and to yield realistic incarnations of the latter and foes on the other hand.

Finally, concerning actual operations, the use of virtual reality is a good tool to create dynamic strategic and tactical situations to be implemented by general staffs. In such cases, it is worthwhile using the workbench or CAVE systems. The combatants themselves will use the enhanced reality techniques that are either already implemented in aeronautics with the head-up displays or being developed for infantrymen in the form of data display on helmet visors.

9.0 - Recommendations

Recommendations are broken down as follows:

- What utilisation of current techniques can be recommended in applications today?
- What scientific searches should be recommended in the technical, methodological and human fields?
- What are the ways to be thoroughly studied in the various military applications?
- What measures can NATO take in the immediate or near future?

9.1 Recommendations concerning the Use of Current Tools in Military Applications

- The workbench-type systems are well suited to architectural design of weapon systems on the one hand, and to be used in actual situations to work out relief maps and monitor changes in military operations on the other hand, but also to be substituted for paper charts in navigation bridges.

- The CAVE-type systems may be used to simultaneously train several infantrymen.

- Virtual reality helmets may be used for training to individual weapon firing, handling instrument panels, in parachute-type simulators.

- Helmet visor displays may be very useful in actual operations to yield enhanced reality. This also applies to the use of 3D sound.

- Artificial feel arms are very attractive for robot remote control.

- In simulators, do not hesitate to merge usual simulation techniques with virtual reality techniques. There are seemingly no applications where the "full virtual" presents a major interest in military applications.

- Finally, it is generally not necessary to yield a genuine environment copy. It will be wiser to display an "ergorama" or visual working space providing the very necessary real and virtual data to achieve the task.

9.2 Recommendations concerning the Major Searching Objectives to be Pursued

- On an industrial basis, this will consist in developing virtual reality helmets with broad vision fields in both the horizontal and vertical planes without increasing their weight or dimensions. Fields of 60° are clearly not wide enough. Another way would consist in exploring creation of images where a wider field images are compressed in the periphery. The principle consists in giving the illusion of a large field without complying with the proportions. It is very likely that this will have no impact on visual perception since the image is blurred in normal peripheral vision.

- It is also necessary that the industry develops new tracking systems to be less restricting for the subjects while making it possible to locate all body segments.

- On a physiological basis, it is seemingly necessary to improve the knowledge on locomotion in order to devise the most useful sensors capable of reporting not only walking moves, but also crawling moves. These searches are of the utmost importance to improve infantrymen systems.

On a psychological basis:

Questionnaires of the Kennedy's type may be used to assess virtual environments and their physical and psychological impacts. However, it remains necessary to undertake searches to thoroughly study the Ender's syndrome and to know how is undergone the use of virtual spaces in actual situations (transition from game to important decision taking in the field).

On a methodological basis:

It remains necessary to develop standard tools to assess the various interfaces used in virtual reality, not only ergonomically, physiologically and psychologically but also in terms of performance and realistic rendering.

9.3 Recommendations concerning the Improvements to be Provided to Military Applications:

- A first issue deals with mission preparation. It is necessary to develop incarnations featuring more realistic expressions and behaviours.

- A second issue deals with actual data transmission from the field that can be integrated in real time into virtual environments.

- A third issue deals with improving the infantryman immersion by developing systems providing for walking, crawling, climbing, going upstairs while additionally making it possible to share a common environment.

9.4 Recommendations in terms of Measures to be Taken by NATO:

- To facilitate or initiate common searches between the NATO countries by using the ESPRIT projects as a guide.

- To recommend researcher exchanges between the NATO countries.

- To recommend to the NATO countries to increasingly rely on civilian researchers (refer to Mike MACEDONIA's presentation during the Hague Workshop about dual technologies).

- To arrange another conference within two years in a view either to take stock on the most recent developments or to analyse the real-life experience on the use of such techniques.

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14. Abstract

Research Study Group 28 (RSG 28) has defined Virtual reality as the experience of being in a synthetic environment and the perceiving and interacting through sensors and effectors, actively and passively, with it and the objects in it, as they were real. VR technology allows the user to perceive and experience sensory contact and interact dynamically with such contact in any or all modalities.

The main goals were: to identify human factors issues involved in the use of VR technology for military purposes; to determine the state of knowledge with regard to those issues and to recommend a research agenda that will address critical questions and enable effective products to be produced to meet the military's needs.

In its five year existence RSG 28 has organised three major workshops addressing these goals and published the results in a number of reports, which are part of this document.

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